US006445842B1

(12) **United States Patent**
Dhuler et al.

(10) **Patent No.: US 6,445,842 B1**
(45) **Date of Patent: Sep. 3, 2002**

(54) **MICROELECTROMECHANICAL OPTICAL CROSS-CONNECT SWITCHES INCLUDING MECHANICAL ACTUATORS AND METHODS OF OPERATING SAME**

(75) Inventors: **Vijayakumar Rudrappa Dhuler**, Raleigh; **Edward A. Hill**, Chapel Hill, both of NC (US)

(73) Assignee: **JDS Uniphase, Inc.** (CA)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/542,170**

(22) Filed: **Apr. 5, 2000**

(51) **Int. Cl.**[7] **G02B 6/26**; G02B 6/42
(52) **U.S. Cl.** **385/17**; 385/18
(58) **Field of Search** 385/16, 17, 18, 385/19, 20–22

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,580,873 A	*	4/1986	Levinson	385/17
5,778,118 A		7/1998	Sridhar	385/24
5,841,917 A	*	11/1998	Jungerman et al.	385/17
5,909,078 A		6/1999	Wood et al.	310/307
5,955,817 A	*	9/1999	Dhuler et al.	310/307
5,960,132 A	*	9/1999	Lin	385/18
5,960,133 A		9/1999	Tomlinson	385/18
5,962,949 A	*	10/1999	Dhuler et al.	310/307
5,974,207 A		10/1999	Aksyuk et al.	385/24
5,994,816 A		11/1999	Dhuler et al.	310/307
5,995,817 A		11/1999	Lubbe et al.	455/266
6,023,121 A		2/2000	Dhuler et al.	310/307
6,144,781 A	*	11/2000	Goldstein et al.	385/18
6,215,222 B1	*	4/2001	Hoen	310/309
6,259,835 B1	*	7/2001	Jing	385/18

OTHER PUBLICATIONS

www.aremco.com, Washaway Mounting Adhesives and Accessories, Technical Bulletin A9.

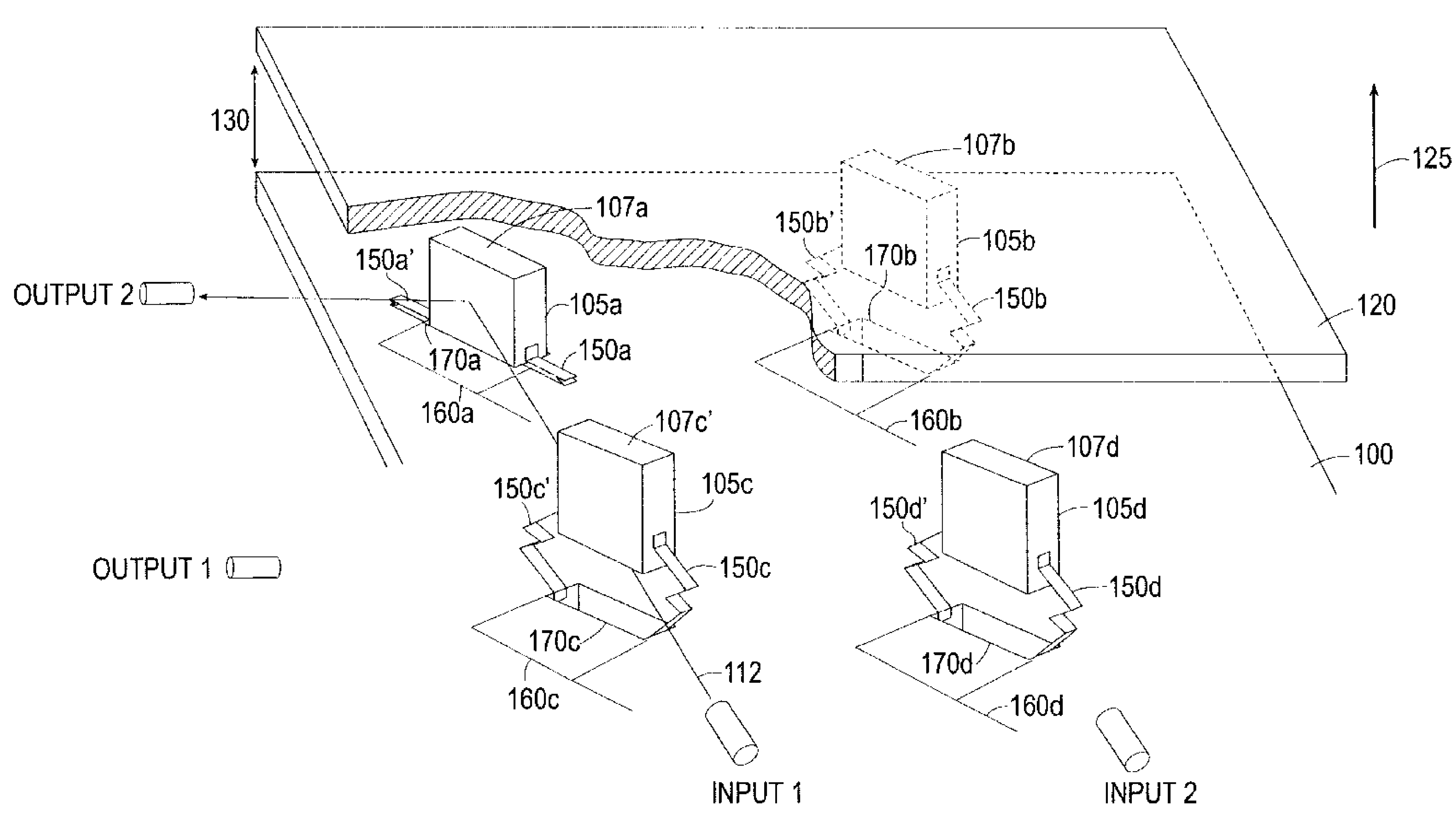
* cited by examiner

Primary Examiner—Hemang Sanghavi
Assistant Examiner—Scott Knauss
(74) *Attorney, Agent, or Firm*—Myers Bigel Sibley & Sajovec, P.A.

(57) **ABSTRACT**

Microelectromechanical (MEM) Optical Cross-connect (OXC) switches having mechanical actuators are discussed. In particular, the MEM OXC switches can include a plurality of reflectors, wherein each of the plurality of the reflectors is movable to at least one of a respective first reflector position along a respective optical beam path from an associated input of the MEM OXC switch to an associated output thereof and a respective second reflector position outside the optical beam path. A mechanical actuator moves to at least one of a first mechanical actuator position and a second mechanical actuator position. A selector selects ones of the plurality of reflectors to be coupled to the mechanical actuator and at least one of the plurality of reflectors to be decoupled from the mechanical actuator, wherein the mechanical actuator is coupled to the selected ones of the plurality of reflectors in the first actuator position and wherein the mechanical actuator moves the selected ones of the plurality of reflectors from the respective first reflector positions to the respective second reflector positions when the mechanical actuator moves from the first mechanical actuator position to the second mechanical actuator position. Related methods are also discussed.

63 Claims, 12 Drawing Sheets



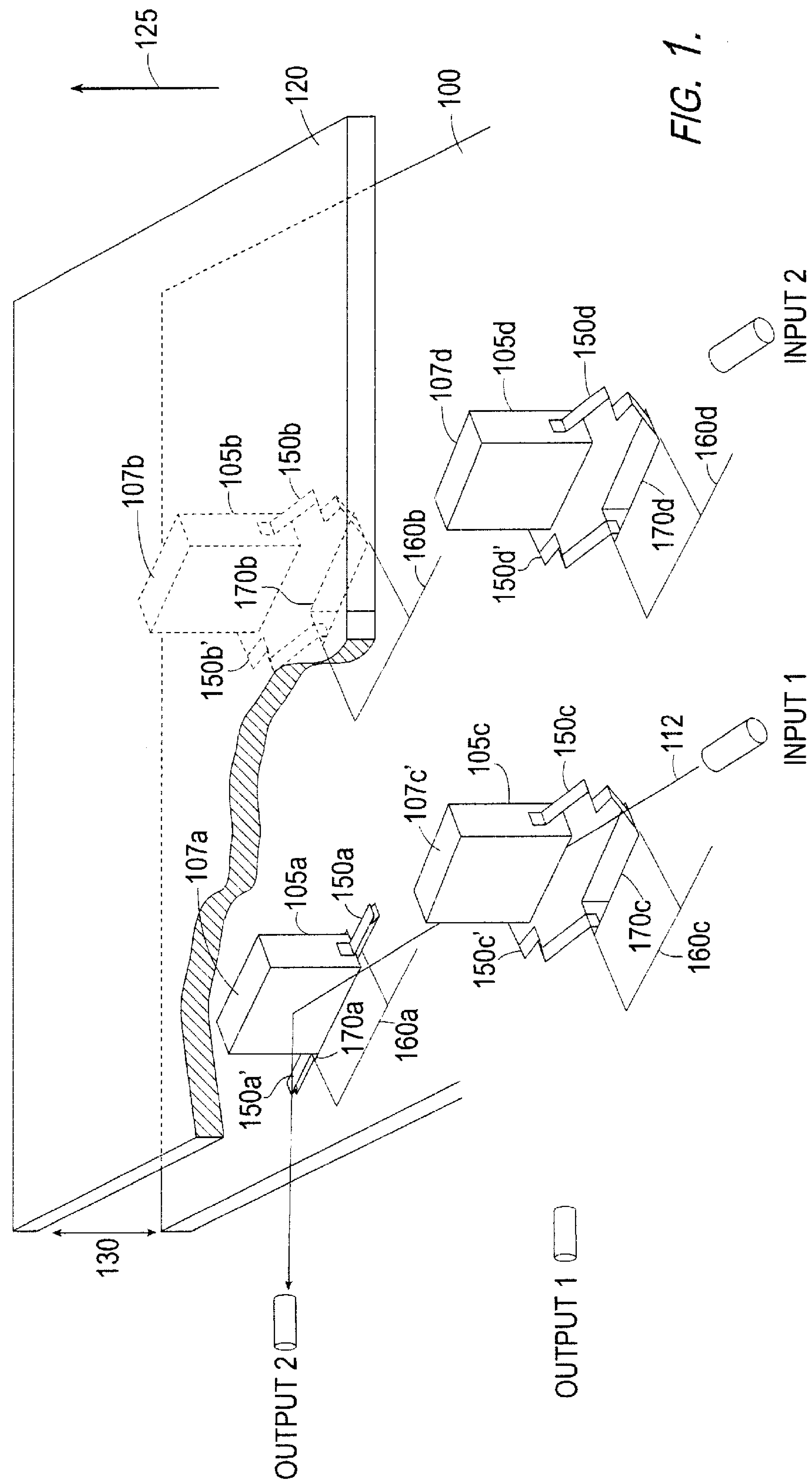

125
120
100
107b
105b
150b
170b
160b
150b'
107d
105d
150d
160d
170d
150d'
INPUT 2
107a
105a
150a
170a
160a
150a'
107c'
105c
150c
112
INPUT 1
170c
160c
150c'
130
OUTPUT 2
OUTPUT 1

FIG. 1.

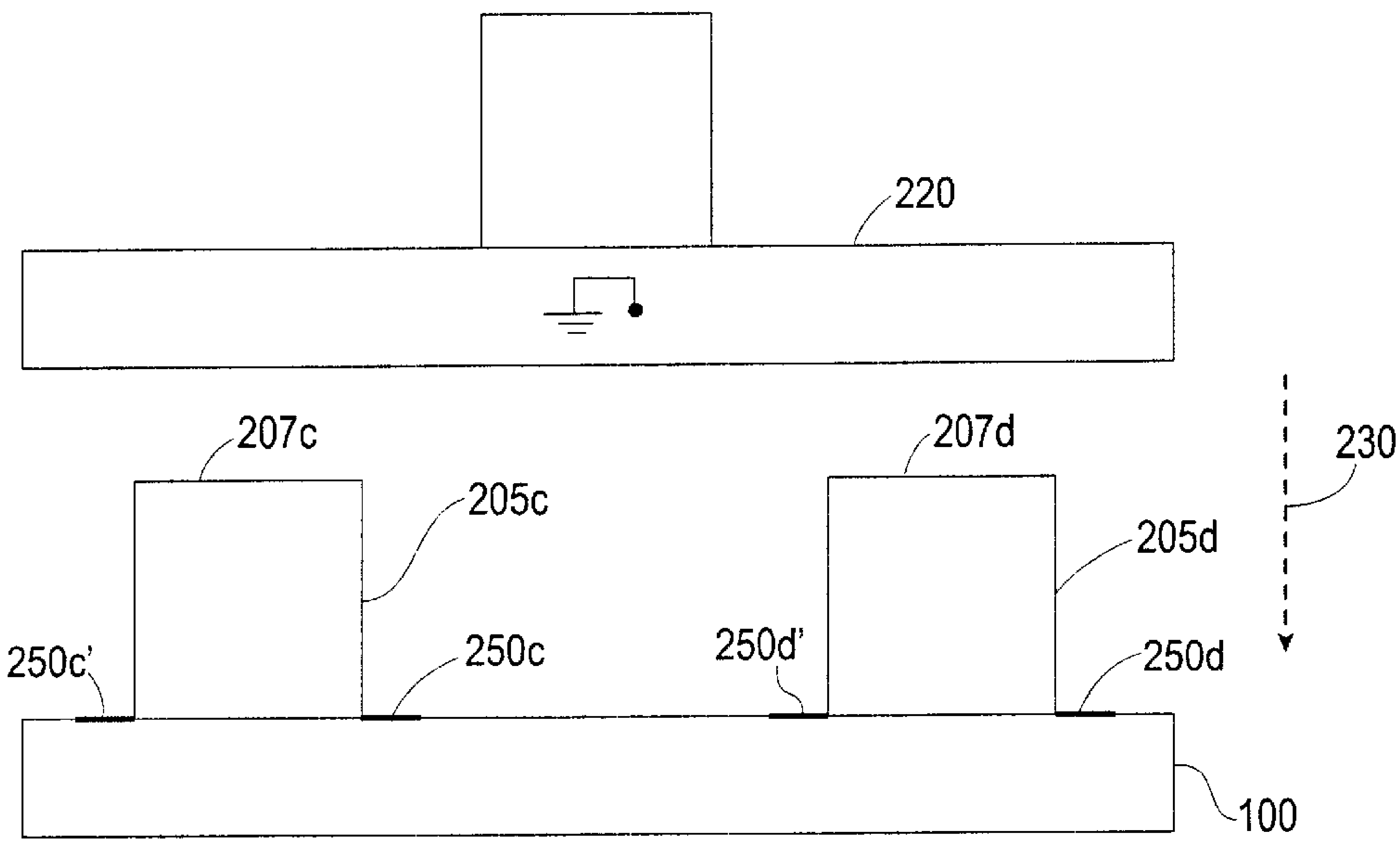

220
207c
205c
207d
205d
230
250c'
250c
250d'
250d
100

FIG. 2A.

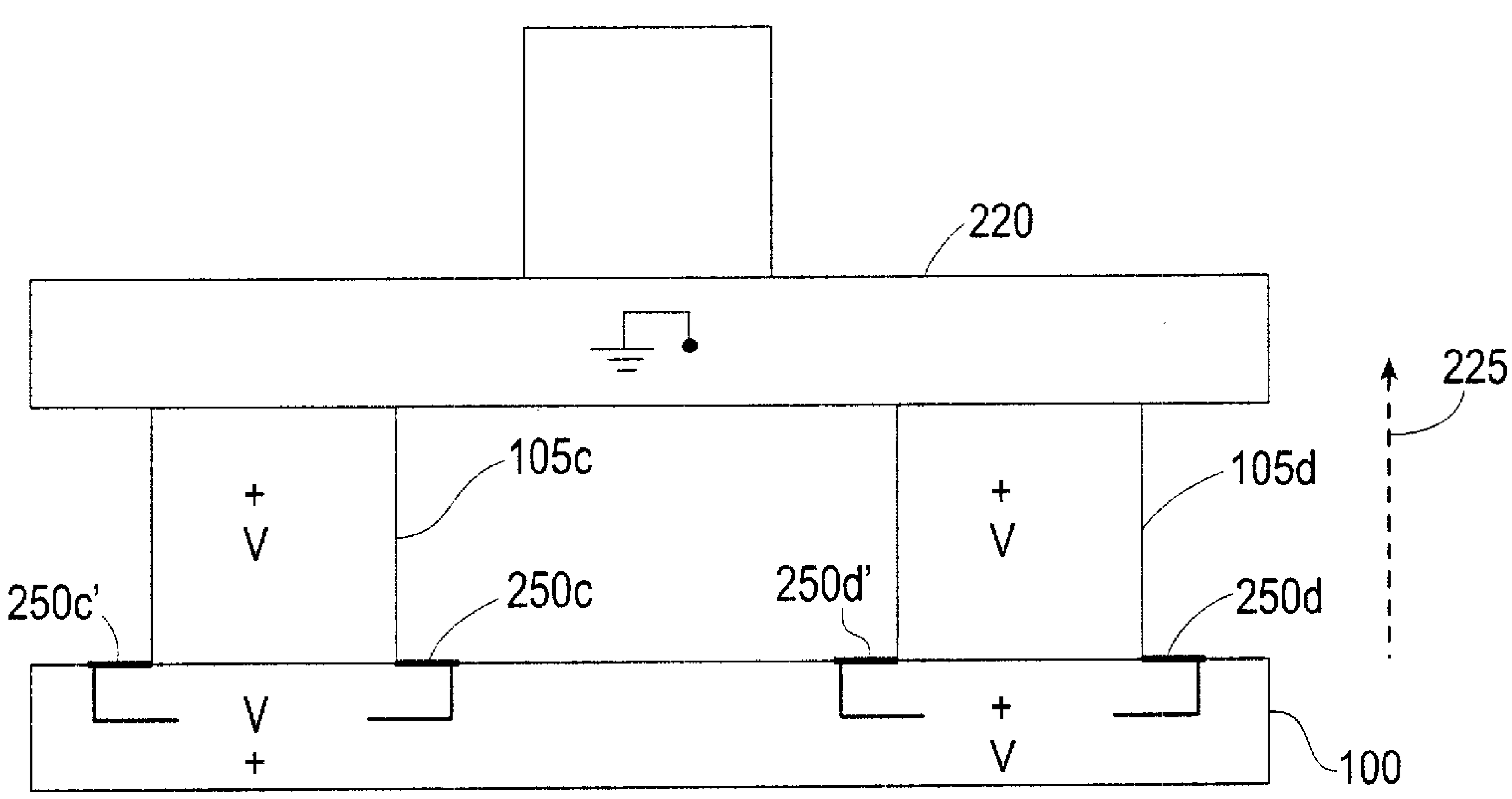

220
225
105c
105d
+
V
250c'
250c
250d'
250d
V
+
100

FIG. 2B.

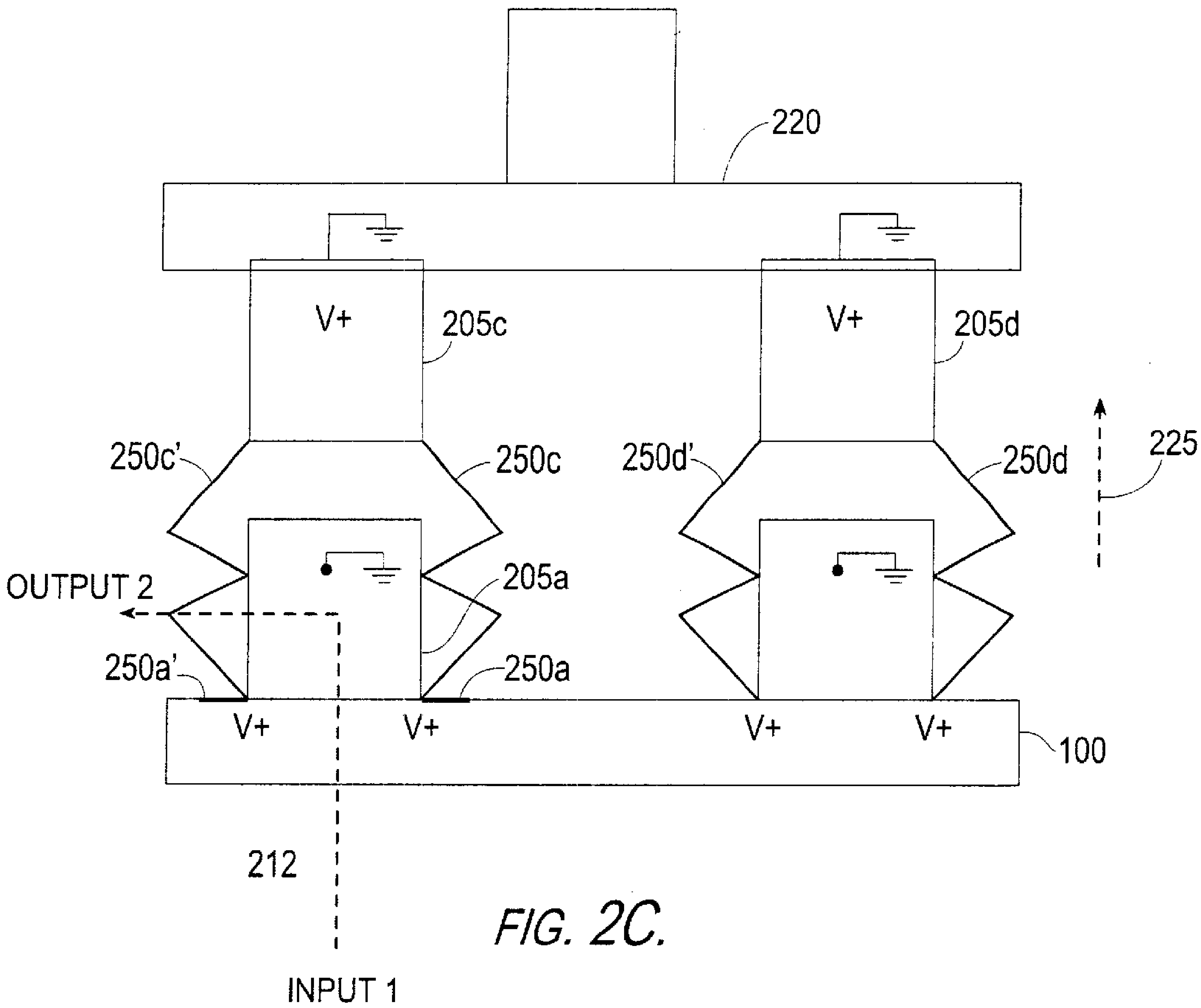

220
V+
205c
V+
205d
225
250c'
250c
250d'
250d
205a
OUTPUT 2
250a'
250a
V+
V+
V+
V+
100
212
INPUT 1

FIG. 2C.

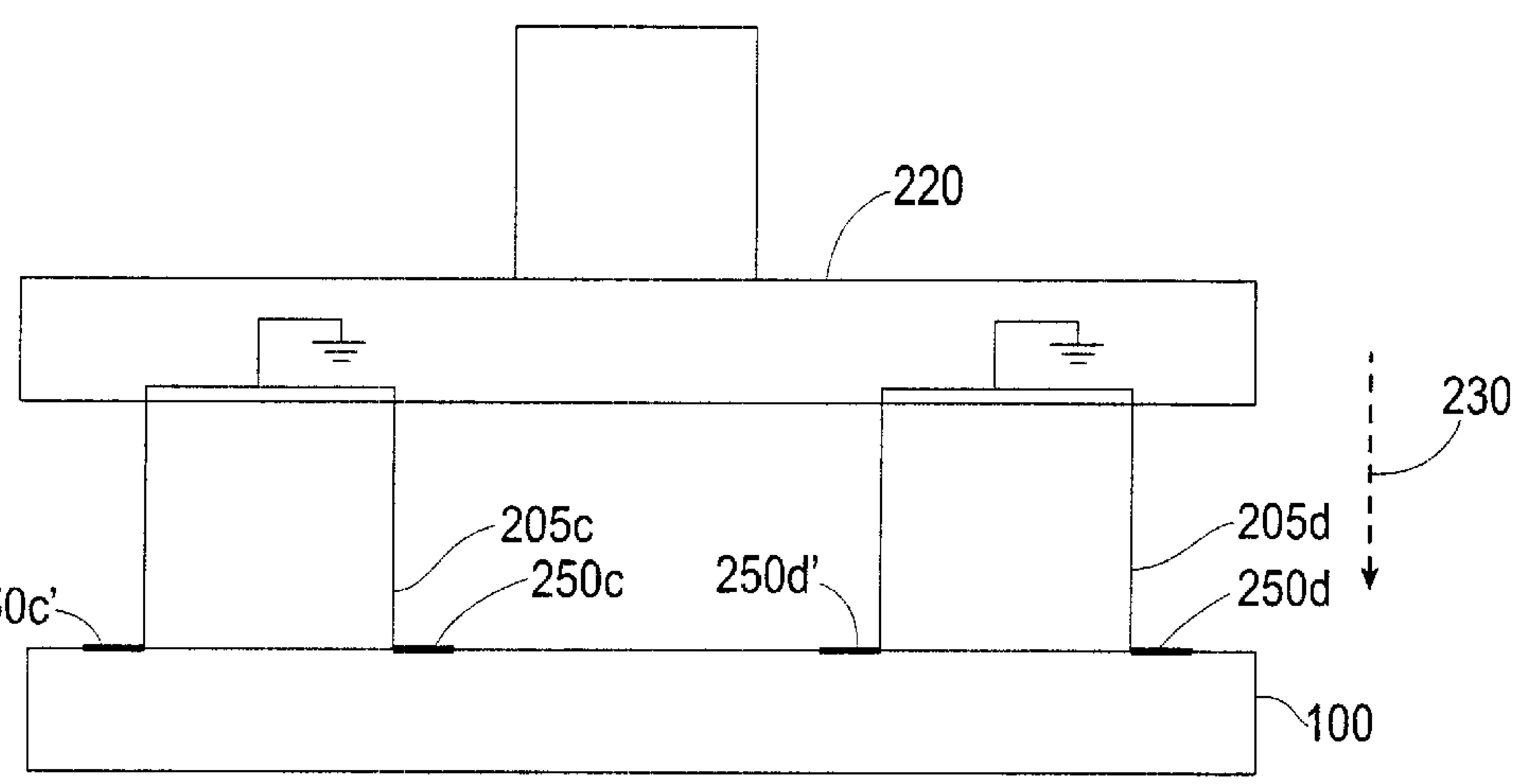

220
230
205c
205d
250c'
250c
250d'
250d
100

FIG. 2D.

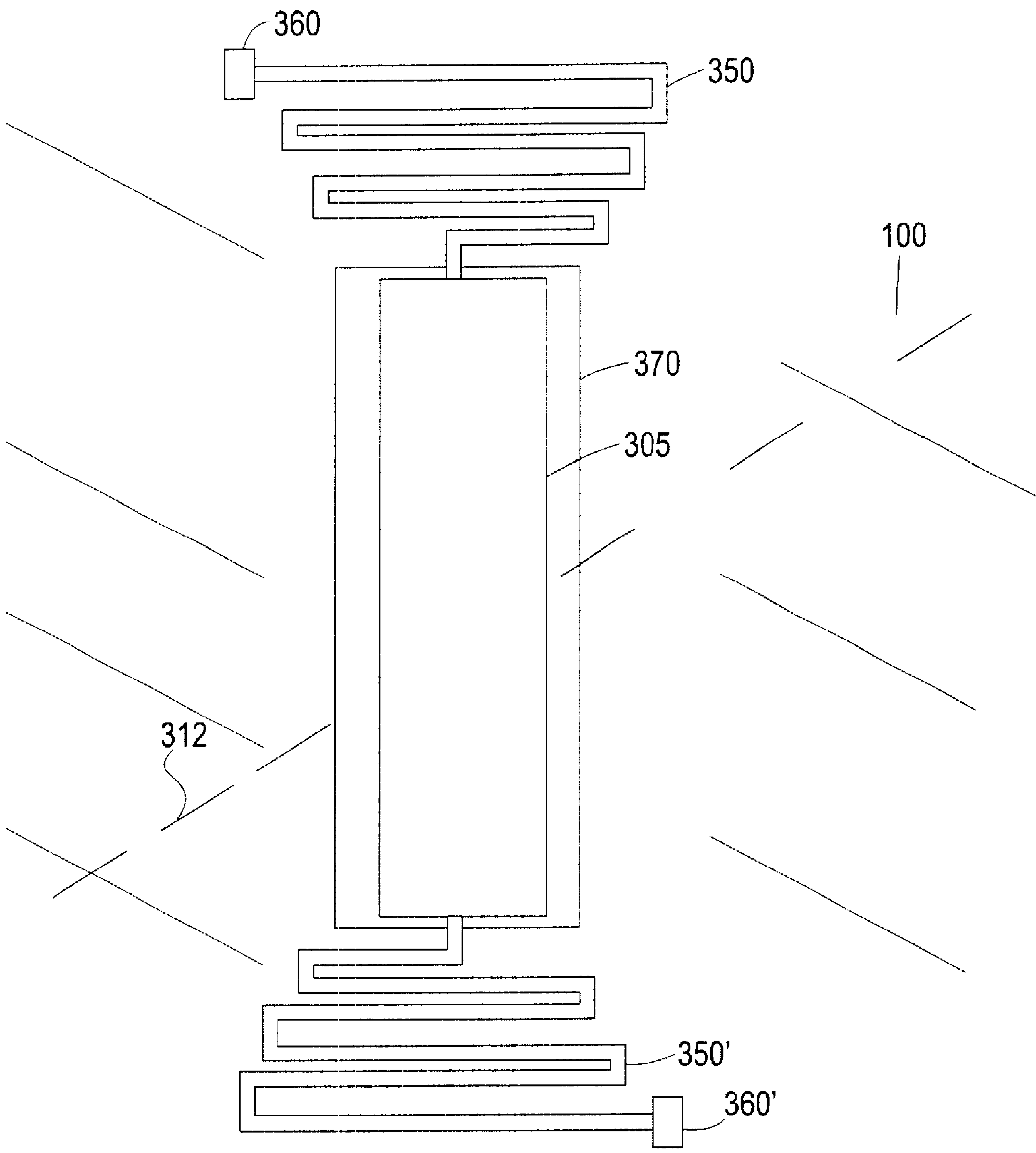


FIG. 3.

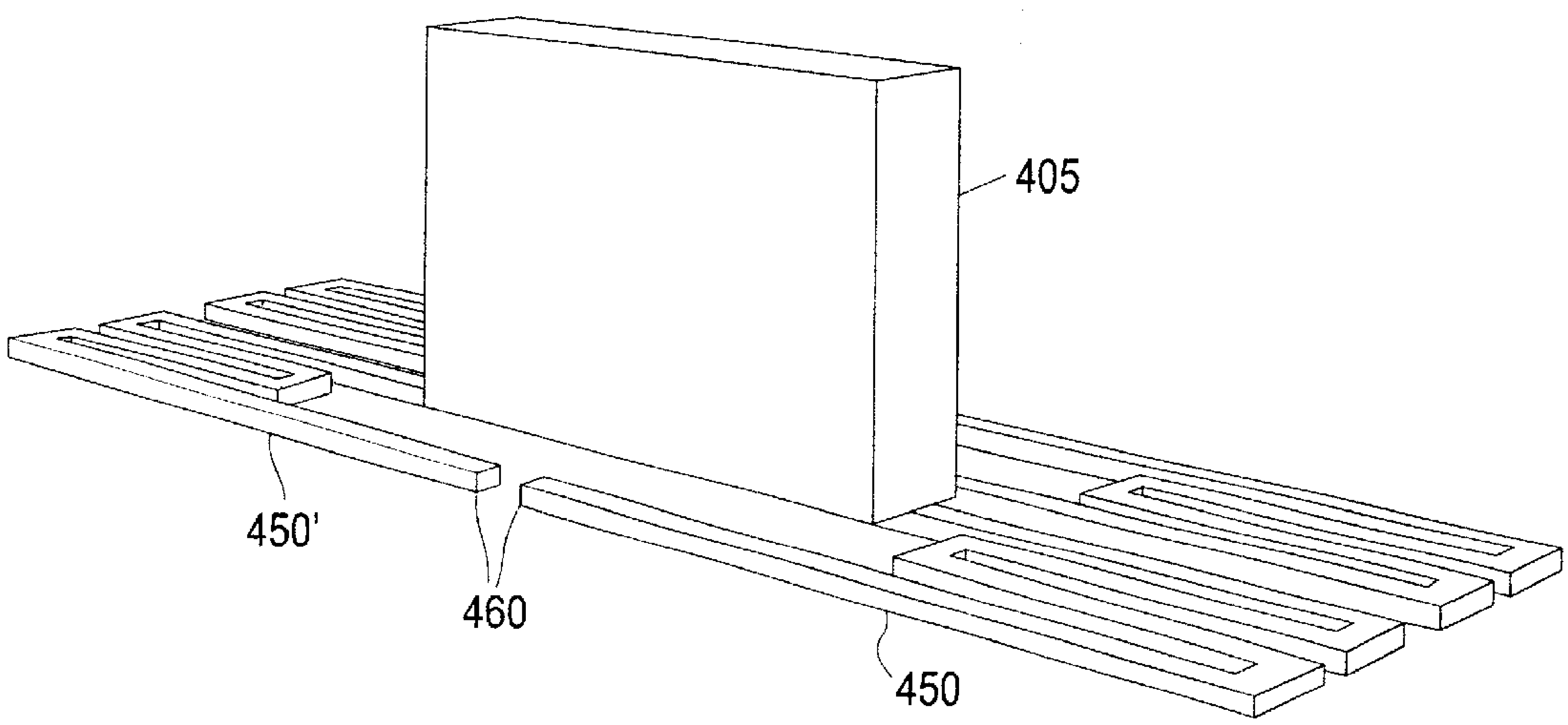


FIG. 4.

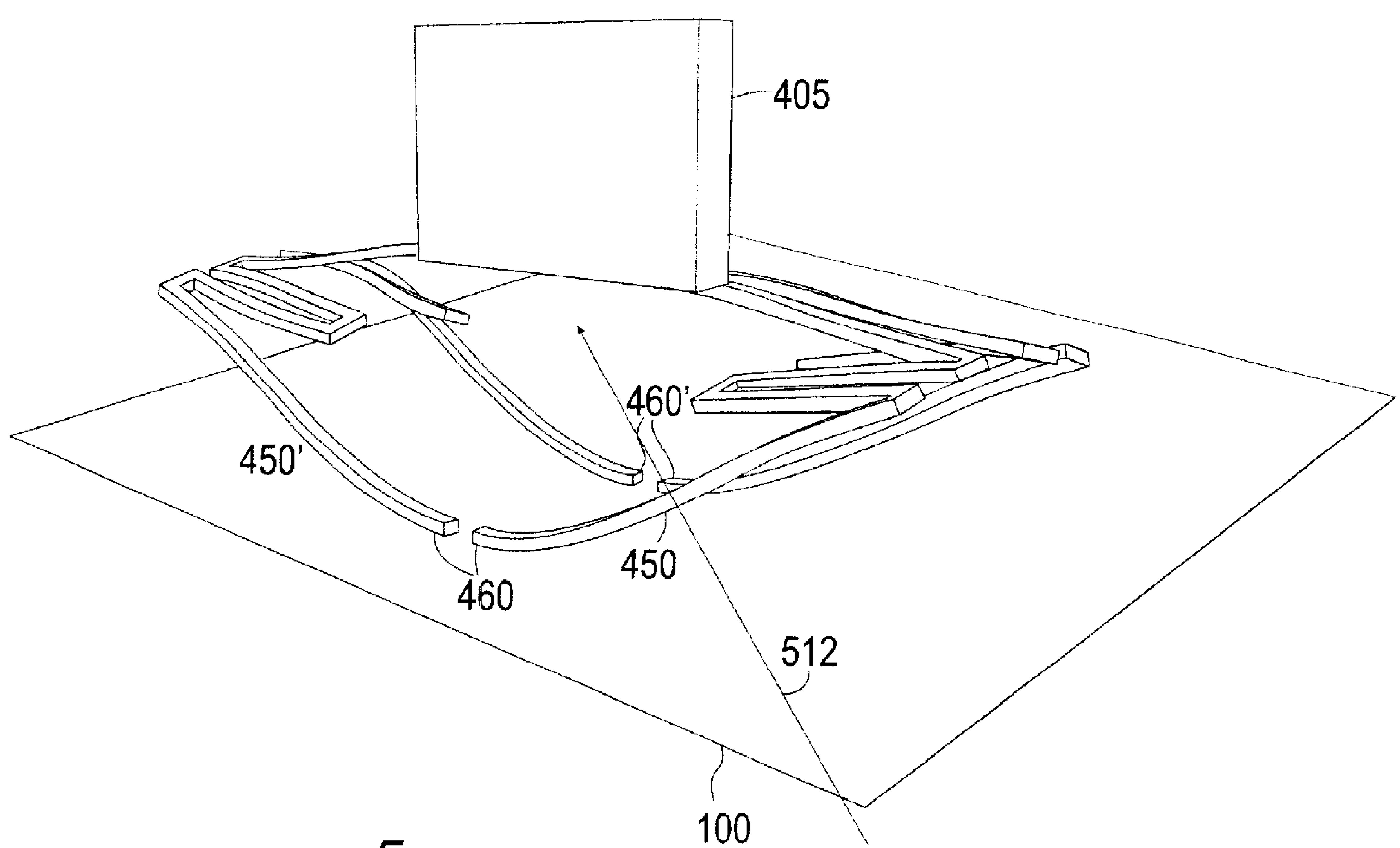


FIG. 5.

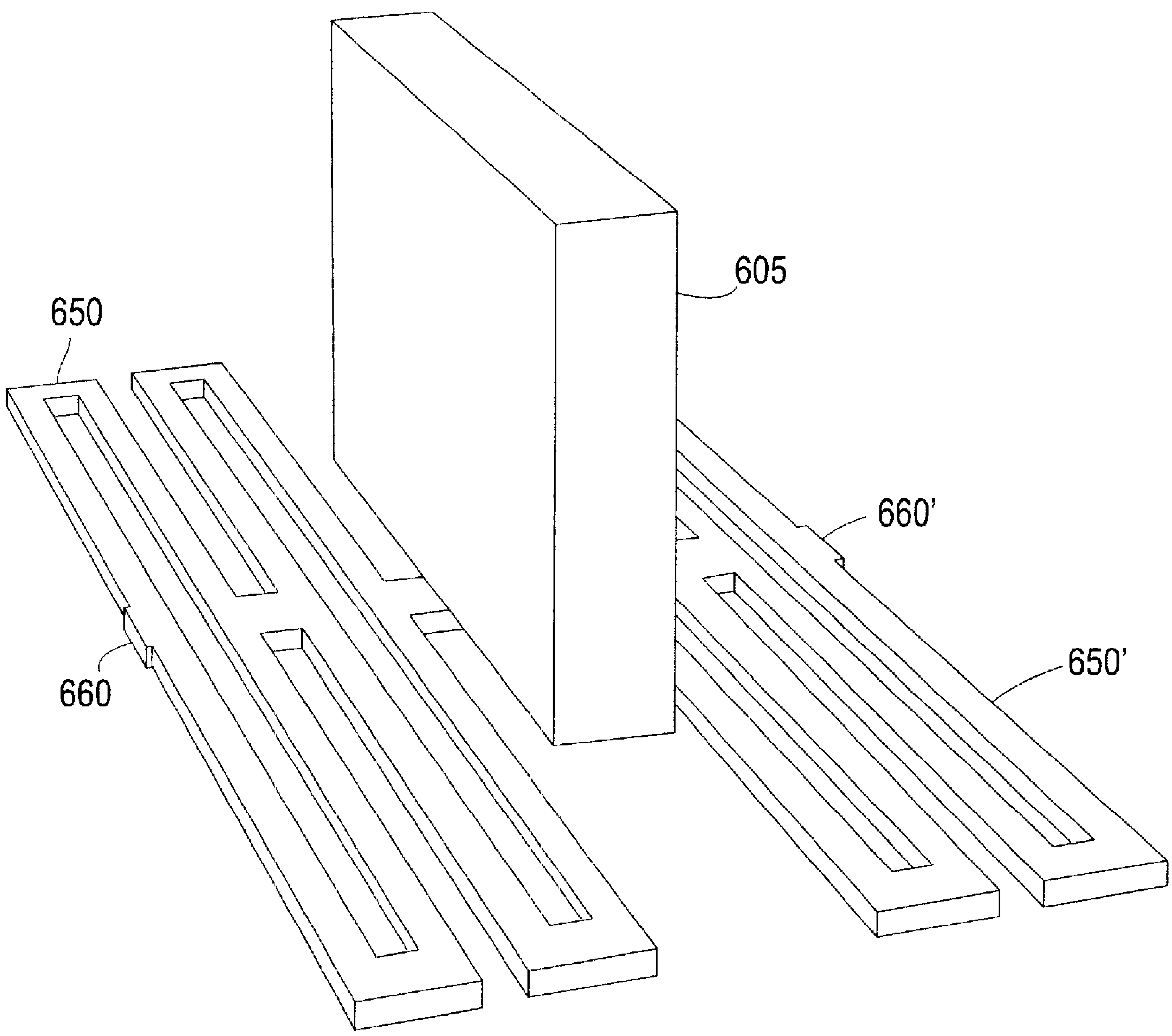


FIG. 6.

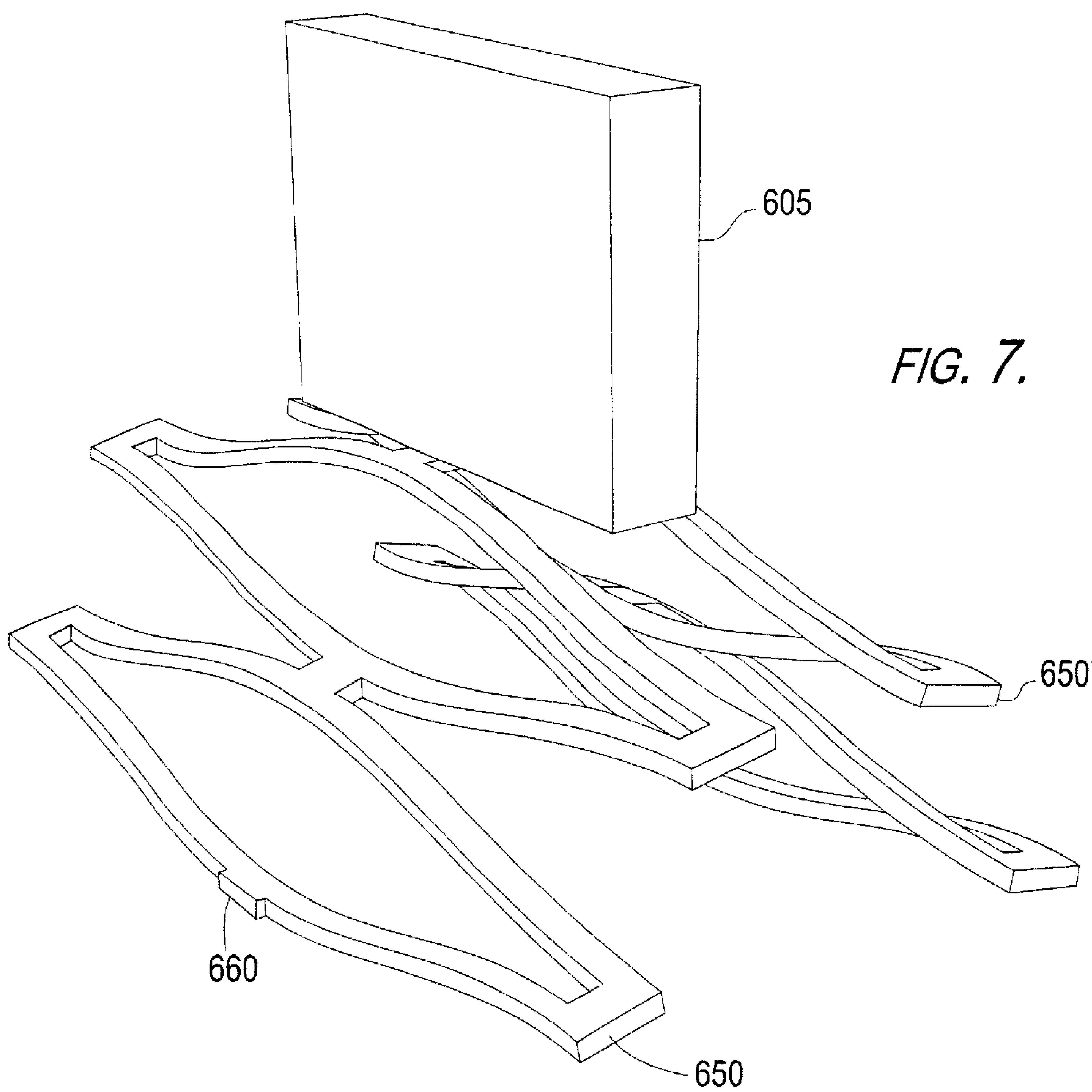


FIG. 7.

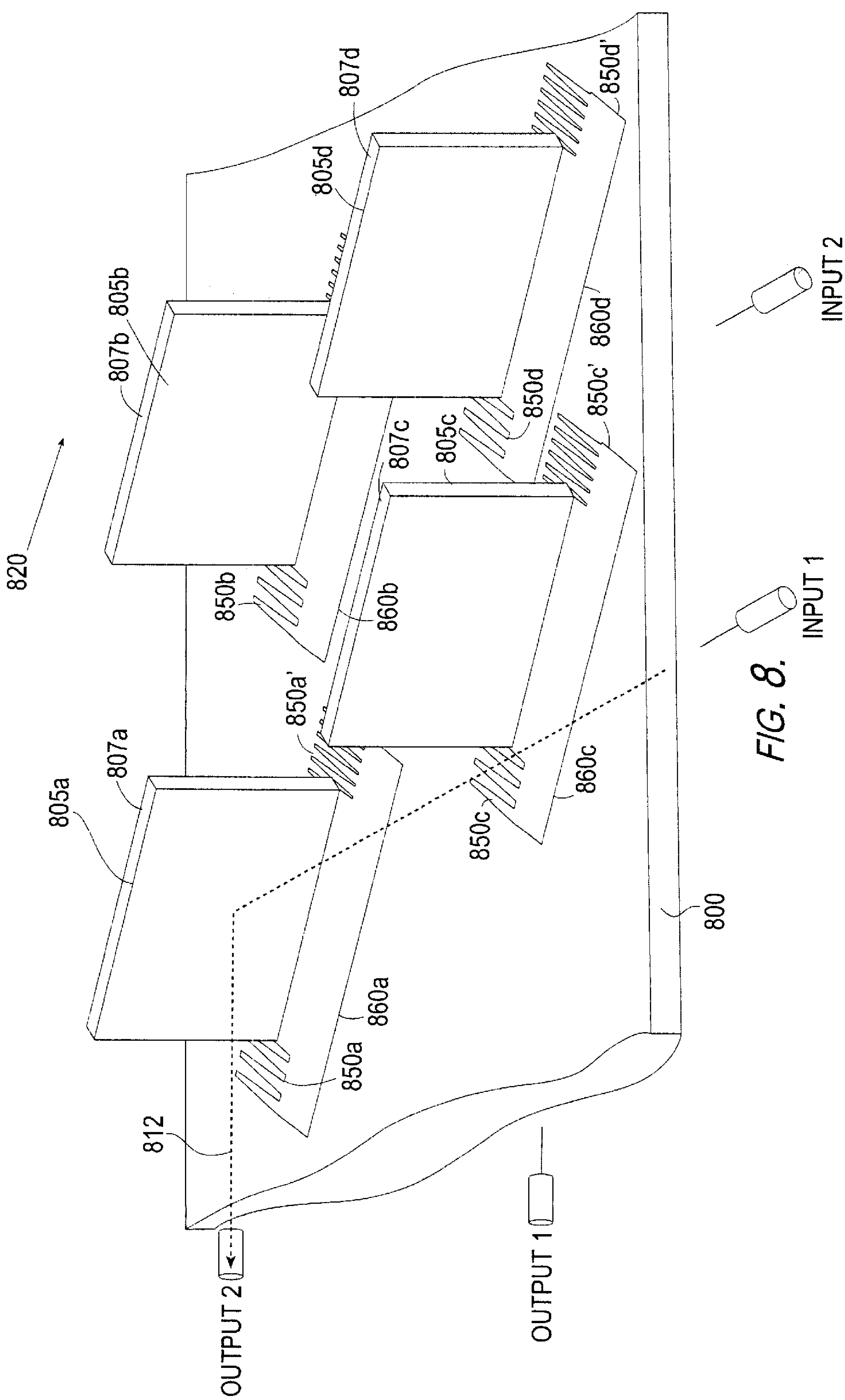

820
805a
807a
850a'
805b
807b
850b
860b
807c
805c
850c
860c
850c'
805d
807d
850d
850d'
860d'
860a
850a
812
800
INPUT 1
INPUT 2
OUTPUT 1
OUTPUT 2

FIG. 8.

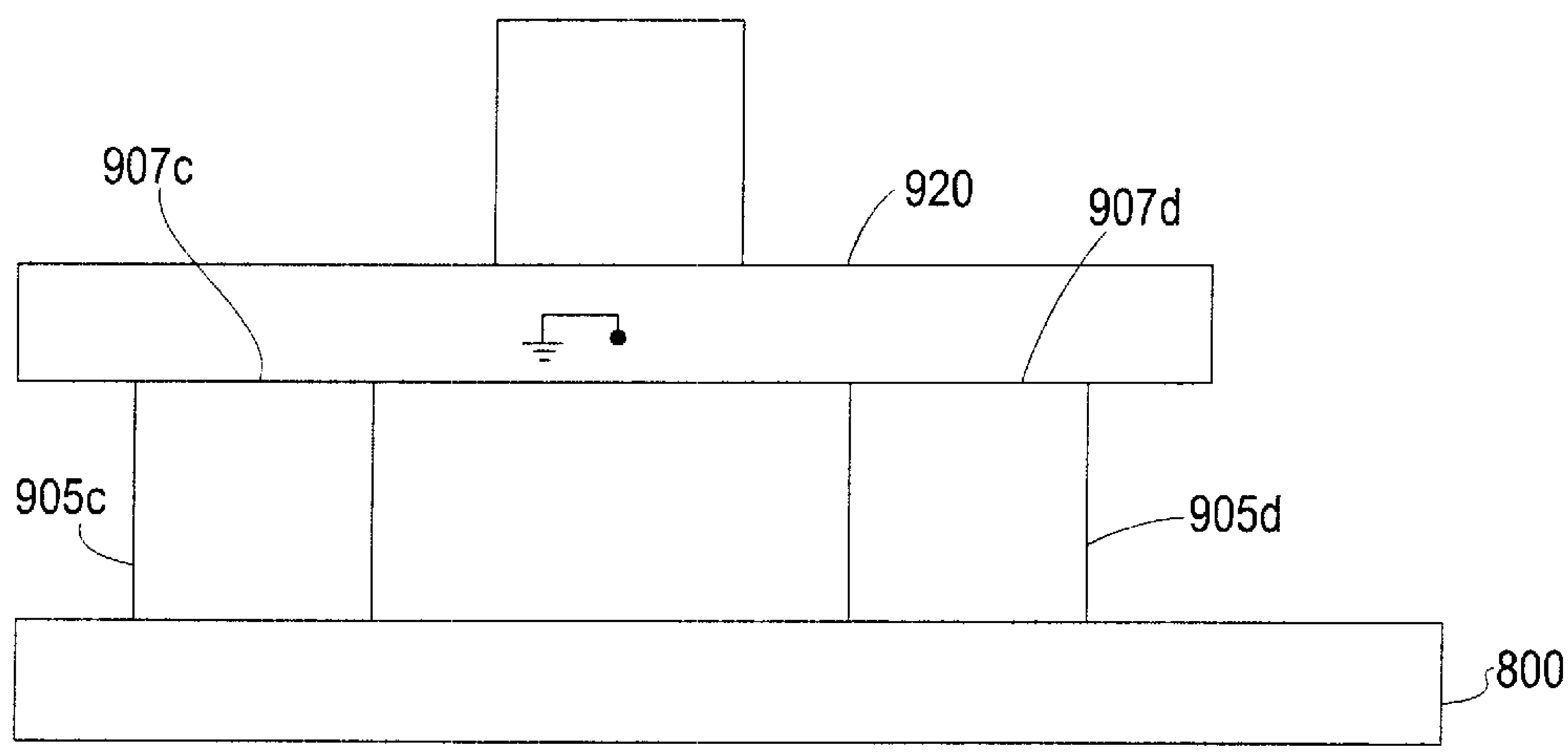

907c
920
907d
905c
905d
800

FIG. 9A.

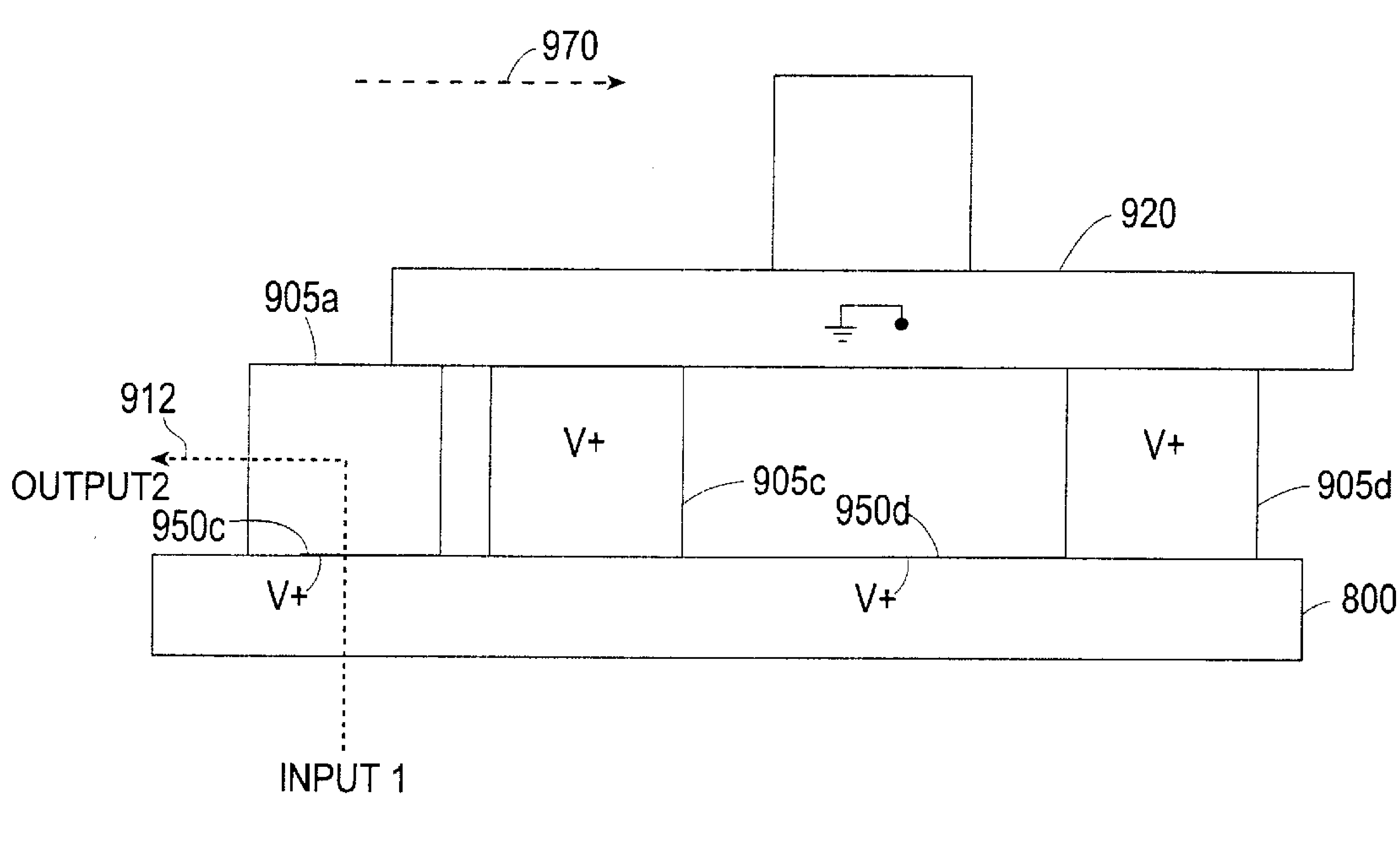

970
920
905a
912
OUTPUT2
950c
V+
905c
950d
V+
905d
V+
V+
800
INPUT 1

FIG. 9B.

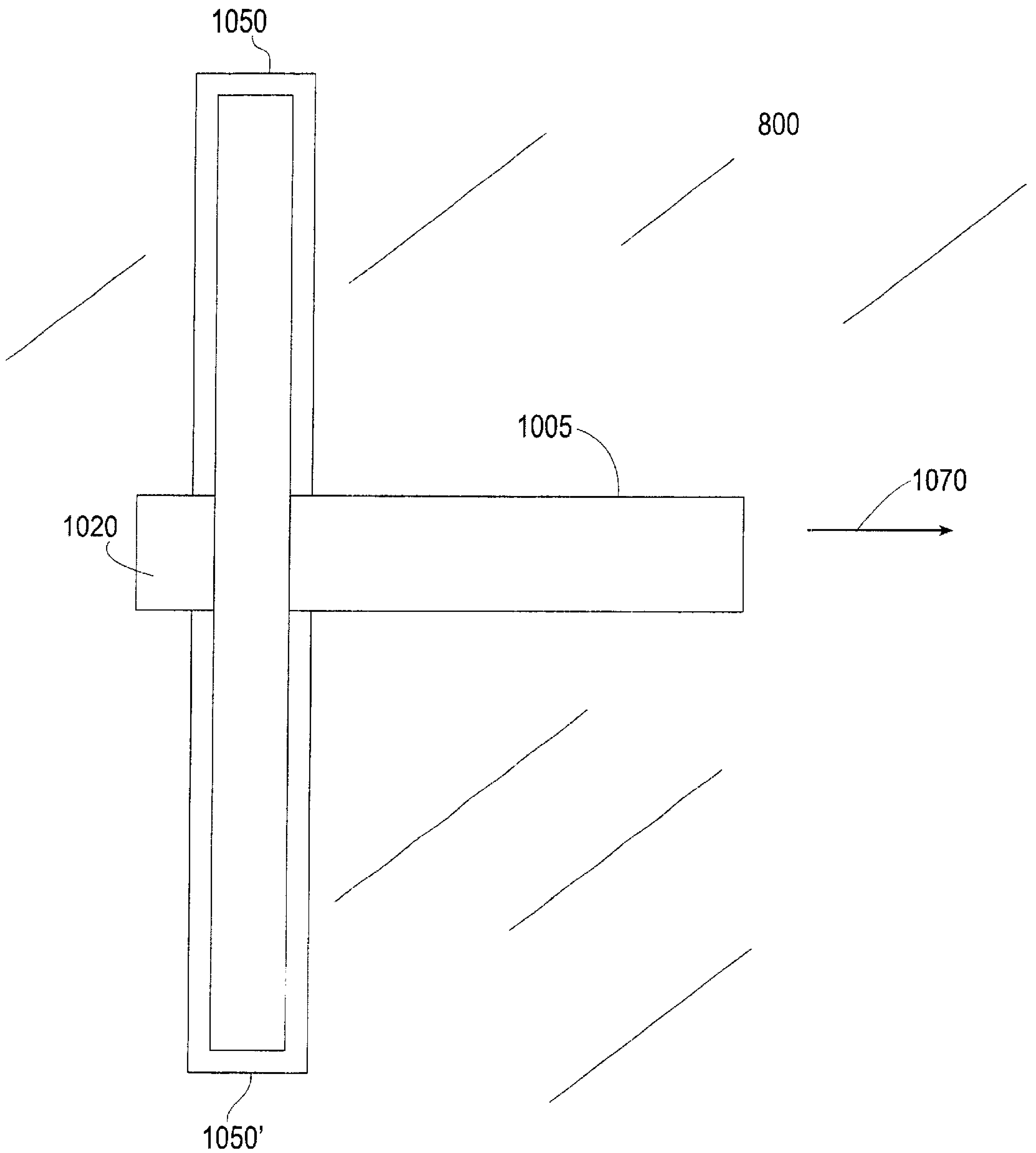


FIG. 10.

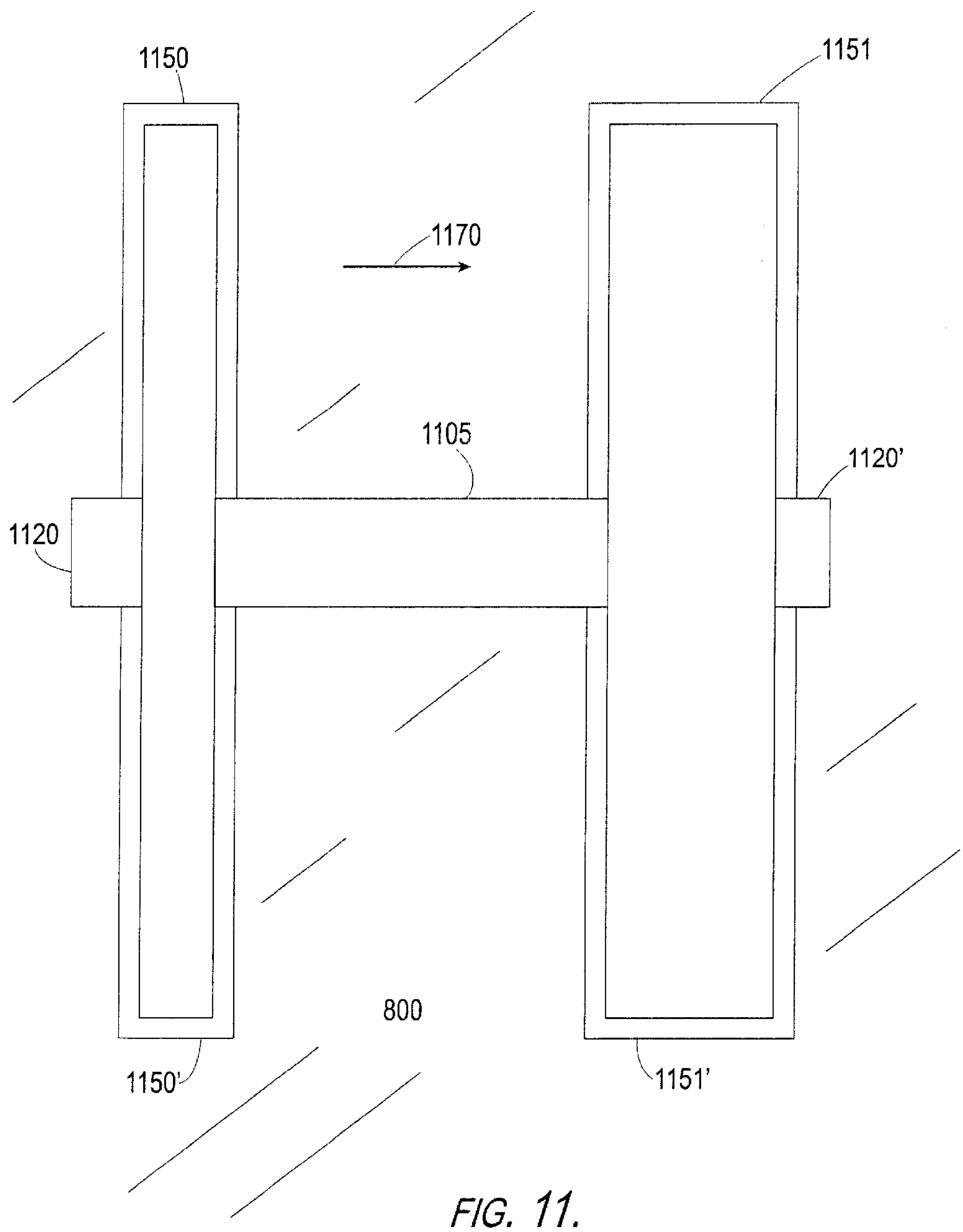


FIG. 11.

MICROELECTROMECHANICAL OPTICAL CROSS-CONNECT SWITCHES INCLUDING MECHANICAL ACTUATORS AND METHODS OF OPERATING SAME

FIELD OF THE INVENTION

The present invention relates to the field of microelectromechanical devices, and more particularly, to microelectromechanical optical switches.

BACKGROUND OF THE INVENTION

Microelectromechanical (MEM) technology has been used in a wide range of applications. For example, MEM devices can be used to switch optical energy from the switch inputs to selected switch outputs. MEM optical switches, sometimes referred to as Optical Cross-Connect (OXC) switches can include an N×N array of reflectors to reflect optical energy from any switch input to any switch output. For example, in a 2×2 OXC, a selected reflector of the 2×2 array can be used to reflect the optical energy from any switch input to any switch output. The selected reflector can be located in the array where the column associated with input and the row associated with the output intersect. The selected reflector can be placed in a reflecting position to reflect the optical energy from the input to the selected output. The other reflectors can be placed in a non-reflecting position so as not to impede the propagation of the optical energy from the input to the selected reflector and to the output.

Some conventional MEM OXC switches operate by orienting the reflectors of the array using magnetic fields. In particular, the reflectors therein may be oriented horizontally (in the plane of the substrate on which the reflector is located) in a non-reflecting position and vertically (orthogonal to the substrate) in a reflecting position. Therefore, to switch optical energy from an input of the OXC switch to an output thereof, the, selected reflector can be oriented vertically and the other reflectors are oriented horizontally. Magnetically actuated MEM OXC switches are described further, for example, in U.S. patent application Ser. No. 09/489,264 filed Jan. 21, 2000, entitled "MEMs Optical Cross-Connect Switch", the disclosure of which is hereby incorporated herein by reference in its entirety.

Unfortunately, reflectors in some magnetically actuated MEM OXC switches may occupy a relative large portion of the substrate, thereby reducing the number of reflectors that may be included in the MEM OXC switch. For example, some magnetically actuated MEM OXC switches orient the reflectors in a horizontal position when the reflectors are in a non-reflective position as described above. Accordingly, the substrate may be over-sized to provide adequate space for all of the reflectors to be oriented horizontally on the substrate. Furthermore, magnetically actuated MEM OXC switches may have localized magnetic actuators located under each reflector. The localized magnetic actuators may, therefore, further increase the area of the substrate which may need to be allocated to each reflector. In view of the above, a need continues to exist to further improve MEM optical switches.

SUMMARY OF THE INVENTION

The present invention can allow improved Microelectromechanical (MEM) Optical Cross-Connect (OXC) switches by providing a plurality of reflectors, wherein the each of the plurality of reflectors is movable to at least one of a respective first reflector position along an optical beam path from an input of the MEM OXC switch to an output thereof and a respective second reflector position outside the optical beam path. A mechanical actuator moves to at least one of a first mechanical actuator position and a second mechanical actuator position. A selector selectively couples at least one of the plurality of reflectors to the mechanical actuator, wherein the at least one of the plurality of reflectors moves from the first reflector position to the second reflector position when the mechanical actuator moves from the first mechanical actuator position to the second mechanical actuator position.

The mechanical actuator can allow a MEM OXC having simplified interconnect therein. In particular, the mechanical actuator may reduce the need to include individual actuation control lines in the MEM OXC. For example, in one embodiment, the mechanical actuator can move all reflectors coupled to the mechanical actuator. Accordingly, the need for controlling which reflectors are actuated may be reduced.

In one embodiment, the mechanical actuator moves in a direction that is substantially perpendicular to a substrate on which the reflectors are located. In another embodiment, the mechanical actuator moves in a direction that is substantially parallel to the substrate on which the reflectors are located.

In a further embodiment, the flexible elements each have a first portion attached to the substrate and a second portion, spaced-apart from the first portion, attached to a respective one of the plurality of reflectors. Each of the plurality of flexible elements allows the attached one of the plurality of reflectors to move between the first and second reflector positions. In another embodiment, the flexible elements can include a third portion spaced-apart from the first and second portions and attached to the substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of an embodiment of a 2×2 Microelectromechanical (MEM) Optical Cross-Connect (OXC) switch according to the present invention.

FIGS. **2A–2D** are schematic cross-sectional views of an embodiment of a 2×2 MEM OXC switch according to the present invention that illustrate operations thereof.

FIG. **3** is a plan view of an embodiment of a reflector having associated flexible elements according to the present invention.

FIG. **4** is a perspective view of another embodiment of a reflector having associated flexible elements according to the present invention.

FIG. **5** is a perspective view of the reflector of FIG. **4** in a non-reflecting position according to the present invention.

FIG. **6** is a perspective view of another embodiment of a reflector having associated flexible elements according to the present invention.

FIG. **7** is a perspective view of the reflector of FIG. **6** in a non-reflecting position according to the present invention.

FIG. **8** is a perspective view of another embodiment of a 2×2 MEM OXC switch according to the present invention.

FIGS. **9A–9B** are schematic cross-sectional views of another embodiment of a 2×2 MEM OXC switch according to the present invention that illustrate operations thereof.

FIG. **10** is a plan view of an embodiment of a flexible element according to the present invention.

FIG. **11** is a plan view of another embodiment of a flexible element according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. In the drawings, the thickness of layers and regions are exaggerated for clarity. Like numbers refer. to like elements throughout.

It will be understood that when an element such as a layer, region or substrate is referred to as being "on" another element, it can be directly on the other element or intervening elements may also be present.

FIG. **1** is a perspective view of an embodiment of a 2×2 MEM OXC according to the present invention. The 2×2 MEM OXC switch (the switch) includes four reflectors **105***a–d* that can be moved from respective reflecting positions to non-reflecting positions by a mechanical actuator **120** that moves from a first to a second mechanical actuator position in a direction **125** that is substantially perpendicular to a substrate **100**. The reflecting position can include reflector positions that allow optical energy from an input to reflect to an output. The non-reflecting position can include reflector positions that avoid the reflection of optical energy from an input to an output. The substrate **100** can be silicon or other materials may be used.

In particular, the reflectors **105***a–d* are organized as an array of 2 columns and 2 rows. Each input is associated with a column in the array. Each output is associated with a row of the array. Optical energy can be reflected from an input to a selected output by positioning a selected reflector **105***a–d* in the reflecting position and positioning the other reflectors **105***a–d* in the non-reflecting position. It will be understood that MEM OXC switches having greater or fewer inputs and outputs and/or a different number of inputs and outputs (i.e., an N×M MEM OXC switch) may be provided using arrays of reflectors include more or less than 4 reflectors.

Each of the reflectors **105***a–d* in a column of the array can be used to reflect optical energy along an optical beam path from the associated input to the associated output. A reflector is selected to reflect optical energy based on the input at which the optical energy is received and the output to which it is to be reflected. For example, as shown in FIG. **1**, reflectors **105***a,c* are associated with the input **1** and reflectors **105***a,b* are associated with output **2**. Therefore, the reflector **105***a* can be used to switch the optical energy from the input **1** to the output **2** along an optical beam path **112**. In operation, the selected reflector **105***a–d* is placed in the reflecting position and the remaining reflectors are placed in the respective non-reflecting positions. It will be understood that the reflectors can be oriented at an angle relative to the optical beam path defined by the associated input and output. For example, the reflector **105***a* can be oriented at 45 degrees relative to the optical beam path **112**.

The mechanical actuator **120** is spaced a first distance **130** apart from the substrate **100** ,in the first mechanical actuator position so that the mechanical actuator **120** contacts respective upper reflector surfaces **107***a–d* of the reflectors **105***a–d*. Alternatively, the mechanical actuator **120** may not contact the upper reflector surfaces **107***a–d* in the first mechanical actuator position, but may be closely spaced-apart from the upper reflector surfaces **107***a–d* in the first mechanical actuator position. The mechanical actuator **120** is spaced a second distance, greater than the first distance **130**, from the substrate **100** when the mechanical actuator **120** is in the second mechanical actuator position. The mechanical actuator **120** moves from the first to the second mechanical actuator position in the direction **125**.

Trenches **170***a–d* may allow for the associated reflector **105***a–d* to be moved in a direction opposite to the direction **125** if the mechanical actuator **120** contacts the associated upper reflector surfaces **107***a–b*. The trenches **170***a–d* may thereby reduce the likelihood of damage to the reflector **105***a–d* and/or the substrate **100** if the mechanical actuator **120** contacts the associated upper reflector surfaces **107***a–b* which may otherwise cause the reflector to contact the substrate **100**.

While in the first mechanical actuator position, the reflectors **105***a–d* to be positioned in the non-reflecting position can be electrostatically coupled to the mechanical actuator **120**. The electrostatic coupling can be provided by maintaining a potential difference between the mechanical actuator **120** and each reflector **105***a–d* to be coupled to the mechanical actuator **120**. In one embodiment, the potential difference is provided by a clamping voltage selectively applied to the reflectors **105***a–d* and a mechanical actuator voltage level applied to the mechanical actuator **120**. Accordingly, the conductors **160***a–d* can provide a selector that selectively couples the reflectors **105***a–d* to the mechanical actuator **120**.

Preferably, the mechanical actuator voltage level is maintained at ground and the clamping voltage level on the conductors can be positive or negative relative to the mechanical actuator voltage level as shown, for example, in FIGS. **2A–2D**. Other voltage levels may be used. Alternatively, the mechanical actuator **120** can include conductors that conduct the clamping voltage to areas of the mechanical actuator **120** associated with the underlying respective reflectors **105***a–d*. For example, the clamping voltage may be applied to selected areas of the mechanical actuator **120** and the reflectors **105***a–d* can be grounded.

The clamping voltage can be provided to the reflectors **105***a–d* to be positioned in the non-reflecting position and withheld from the reflector to be positioned in the reflecting position. For example, according to FIG. **1**, to reflect optical energy from the input **1** to the output **2**, the reflectors **105***b–d* are provided with the clamping voltage and reflector **105***a* is not provided with the clamping voltage. Accordingly, the reflectors **105***b–d* are coupled to the mechanical actuator **120** and the reflector **105***a* is decoupled from the mechanical actuator **120**. The clamping,voltage can be provided from the conductors **160***a–d* to the selected reflectors **105***a–d* via flexible elements discussed herein.

In another embodiment according to the present invention, the reflectors **105***a–d* can be mechanically coupled to the mechanical actuator **120**. In particular, the mechanical coupling may be provided by a thermoplastic material. The thermoplastic material can be located on the mechanical actuator **120** opposite the reflectors **105***a–d*. When a selected reflector **105***a–d* is to be moved, the thermoplastic material opposite the selected reflector **105***a–d* is heated and the mechanical actuator **120** is placed in contact with selected reflector **105***a–d* whereupon the heating stops. When the thermoplastic material is dry, it mechanically couples the selected reflector **105***a–d* to the mechanical actuator **120**. The thermoplastic material can be heated by a heater located on the mechanical actuator **120**. The use of thermoplastic material is discussed further, for example, in U.S. patent application Ser. No. 09/543540, entitled Lockable MicroElectroMechanical Actuators Using Thermoplastic Material, and Methods of Operating Same filed Apr. 5, 2000.

When the mechanical actuator **120** is moved in the direction **125**, the reflectors **105***a–d* coupled to the mechanical actuator **120** are moved from the reflecting position to the non-reflecting position. Moreover, the reflector **105***a–d* that is decoupled from the mechanical actuator **120** remains in the reflecting position when the mechanical actuator **120** moves from the first to the second mechanical actuator position, thereby enabling the optical energy to be reflected from the input to the output along the optical beam path.

The mechanical actuator can be, for example, an inductively driven servo mechanism or a precision stepper-motor that can be used to control the position of a plate attached to the mechanical actuator **120**. In operation, the mechanical actuator **120** can move at a rate of about 18 microns per millisecond with an accuracy of 2 microns per inch of movement. Such mechanisms are marketed, for example, by TS Products, Inc. located at 5550-2 North McGuire Rd., Post Falls, Id. 83854, and are described on the Internet at http://www.tsproducts.com.

First and second flexible elements **150***a–d*, **150***a–d* are attached to the associated reflectors **105***a–d* and the substrate **100**. The first and second flexible elements **150***a–d*, **150***a–d* can allow the associated reflectors **105***a–d* to move between the reflecting and non-reflecting positions in response to the movement of the mechanical actuator **120**. Otherwise, the first and second flexible elements **150***a–d*, **150***a'–d'* hold the associated reflectors **105***a–d* in the respective reflecting position. For example, as shown in FIG. **1**, the first and second flexible elements **150***b–c*, **150***b'–c'* can extend to allow the coupled reflectors **105***b–d* to be moved to the non-reflecting position in response to the movement of the mechanical actuator **120**.

In another embodiment, only those reflectors **105***a–d* located in the row and column associated with the input and output are moved. For example, referring to FIG. **1**, to switch optical energy from the input **1** to the output **2** along the optical beam path **112**, the reflectors **105***a–d* can remain in the reflecting position and the reflector **105***c* is moved to the non-reflecting position. The reflectors **105***b,d* remain in reflecting position. In other words, the selected reflector **105***a* is placed in the reflecting position and only the reflectors that may otherwise block the optical beam path **112** are,moved to the non-reflecting positions. The other reflectors may remain in the respective reflecting positions.

In another embodiment according to the present invention, the non-reflecting and reflecting positions are reversed from those described above. In particular, the reflectors to be placed in the reflecting position can be clamped to and moved by the mechanical actuator and the reflectors to remain in the non-reflecting position can be unclamped from and unmoved by the mechanical actuator. The inputs, outputs, and the optical beam paths therebetween can also be offset from those described above so that the reflectors that are moved to the reflecting position intersect the offset optical beam paths and the reflectors that remain in the non-reflecting position do not intersect the optical beam path.

FIGS. 2A–D are cross-sectional views illustrating exemplary operations of an embodiment of a 2×2 MEM OXC having a mechanical actuator **220** that moves substantially, perpendicular to the substrate **100**. It will be understood that the elements shown in FIGS. 2A–D are shown schematically and that reflectors **205***a–b* can be occluded by the reflectors **205***c–d*.

According to FIG. 2A, the mechanical actuator **220** moves from the second mechanical actuator position in a first direction **230**, substantially perpendicular to the substrate **100**, towards the reflectors **205***a–d* in the respective reflecting positions. In FIG. 2B, the mechanical actuator **220** contacts the upper reflector surfaces **207***a–d* whereupon the clamping voltage is applied to the reflectors **205***b–d* thereby electrostatically clamping the reflectors **205***b–d* to the mechanical actuator **220**. The clamping voltage is not applied to the selected reflector **205***a*. Accordingly, the selected reflector **205***a* is decoupled from the mechanical actuator **220**. Alternatively, the mechanical actuator **220** can include conductors that conduct the clamping voltage to areas of the mechanical actuator **220** adjacent to the underlying respective reflectors. For example, the clamping voltage may be applied to the areas of the mechanical actuator **220** while the reflectors **205***b–d* are grounded.

According to FIG. 2C, the mechanical actuator **220** is moved in a second direction **225** to the second mechanical actuator position which moves the coupled reflectors **205***b–d* to the respective non-reflecting positions. The selected reflector **205***a* remains in the reflecting position. First and second flexible elements **250***b–d*, **250***b'–d'* extend as shown (remaining outside the optical beam path **212** from the input to the output) to allow the coupled reflectors **205***b–d* to move. According to FIG. 2D, the mechanical actuator **220** moves back to the first mechanical actuator position, whereupon a new arrangement of coupling and decoupling may be provided.

FIG. **3** is a plan view of an embodiment of a reflector **305** on a trench **370** in a substrate **100** having associated first and second flexible elements **350, 350'**. As shown in FIG. **3**, the first and second flexible elements **350**, **350'** can have a u shaped zig-zag pattern. Other patterns may be used. For example, the flexible elements can have be w shaped zig-zag pattern or a closed rectangular shape. The first and second flexible elements **350, 350'** are attached to the substrate **100** via first and second anchors **360, 360'** respectively and to the reflector **305**. When the reflector **305** is moved to the non-reflecting position, the first and second flexible elements **350, 350'** extend and remain outside an optical beam path **312**.

FIG. **4** is a perspective view of an embodiment of a reflector **405** on a substrate **100** having associated first and second flexible elements **450, 450'**. According to FIG. **4**, the first and second flexible elements **450, 450'** can have a u shaped zig-zag pattern. Other patterns may be used. For example, the first and second flexible elements **450, 450'** are attached to the substrate **100** via first and second anchors **460, 460'** and to the reflector **405**. The first and second anchors **460, 460'** are located on the substrate **100** adjacent to a reflective surface of the reflector **405**. When the reflector **405** is moved to the non-reflecting position, the first and second flexible elements **460, 460'** extend and remain outside an optical beam path **512** as shown in FIG. **5**.

FIG. **6** is a perspective view of an embodiment of a reflector **605** on a substrate **100** having associated first and second flexible elements **650, 650'**. According to, FIG. **6**, the first and second flexible elements **650, 650'** can have a closed rectangular pattern. Other patterns can be used. For example, the first and second flexible elements **650, 650'** are attached to the substrate **100** via first and second anchors **660, 660'** and to the reflector **605**. The first and second anchors **660, 660'** can be located on the substrate **100** adjacent to a reflective surface of the reflector **605** and a non-reflective surface opposite the reflective surface. When the reflector **605** is moved to the non-reflecting position, the first and second flexible elements **650, 650'** extend as shown in FIG. **7**.

FIG. **8** is a perspective view illustrating another embodiment of a 2×2 MEM OXC switch according to the present invention. The 2×2 MEM OXC switch (the switch) includes four reflectors **805***a–d* that can be moved from respective reflecting to non-reflecting positions by a mechanical actuator (not shown) that moves substantially parallel to a substrate **800** from a first to a second mechanical actuator position. The reflecting position can include reflector positions that allow optical energy from an input to reflect to an output. The non-reflecting position can include reflector positions that avoid the reflection of optical energy from an input to an output. The substrate **800** can be silicon or other materials may be used.

In particular, the reflectors **805***a–d* are organized as an array of 2 columns and 2 rows. Each input is associated with a column in the array. Each output is associated with a row of the array. Optical energy can be reflected from an input to a selected output by positioning a selected reflector **805***a–d* in the reflecting position and positioning the other reflectors **805***a–d* in the non-reflecting position. It will be understood that MEM OXC switches having greater or fewer inputs and outputs and/or a different number of inputs and outputs (i.e., an N×M MEM OXC switch) may be provided using arrays of reflectors include more or less than 4 reflectors.

Each of the reflectors **805***a–d* in a column of the array can be used to reflect optical energy along an optical beam path from the associated input to the output associated with the row. A reflector **805***a–d* is selected to reflect optical energy based on the input at which the optical energy is received and the output to which it is to be reflected. For example, as shown in FIG. **8**, reflectors **805***a,c* are associated with the input **1** and reflectors **105***a,b* are associated with output **2**. Therefore, reflector **805***a* can be used to switch the optical energy from the input **1** to the output **2** along an optical beam path **812**.

In operation, the selected reflector **805***a–d* is placed in the reflecting position and the remaining reflectors are placed in the respective non-reflecting positions. It will be understood that the reflectors can be oriented at an angle relative to the optical beam path defined by the associated input and output. For example, the reflector **805***a* can be oriented at 45 degrees relative to the optical beam path **812**.

The mechanical actuator contacts respective upper reflector surfaces **807***a–d* of the reflectors, **805***a–d* when the mechanical actuator is in the first mechanical actuator position. Alternatively, the mechanical actuator may not contact the upper reflector surfaces **807***a–d* in the first mechanical actuator position, but may be closely spaced-apart from the upper reflector surfaces **807***a–d*. In the second mechanical actuator position, the mechanical actuator is shifted in a direction **870** substantially parallel to the substrate **800** while remaining in contact with the upper reflector surfaces **807***a–d*.

In the first mechanical actuator position, the reflectors **805***a–d* to be positioned in the non-reflecting position can be electrostatically coupled to the mechanical actuator. The electrostatic coupling can be provided by maintaining a potential difference between the mechanical actuator and each reflector **805***a–d* to be positioned in the non-reflecting position. A clamping voltage level can be provided to each of the reflectors **805***a–d* by respective conductors **860***a–d*. Preferably, the mechanical actuator voltage level is maintained at ground and the clamping voltage level is positive or negative relative to the mechanical actuator level. Other voltage levels may be used.

The clamping voltage level can be provided to the reflectors **805***a–d* to be positioned ink the reflecting position and withheld from the reflector **805***a–d* to be positioned in the reflecting position. For example, according to FIG. **8**, to reflect optical energy from the input **1** to the output **2**, the reflectors **805***b–d* can be provided with the clamping voltage and reflector **805***a* is not provided with the clamping voltage. Accordingly, the reflectors **805***b–d* are coupled to the mechanical actuator and the reflector **805***a* is decoupled from the mechanical actuator.

When the mechanical actuator is moved in the direction **870** to the second mechanical actuator position, the coupled reflectors **805***a–d* coupled to the mechanical actuator are shifted, substantially parallel to the substrate **800,** from the respective reflecting positions to the non-reflecting positions. Moreover, the reflector **805***a–d* that is decoupled from the mechanical actuator remains in the reflecting position when the mechanical actuator moves from the first to the second mechanical actuator position, thereby moving the reflector **805***c* outside the optical beam path **812** and enabling the optical energy to be reflected from the input **1** to the output **2**.

In another embodiment, the movement of the mechanical actuator in the direction **870** is used to rotate the reflectors **805***a–d* from a reflecting position perpendicular to the substrate **800** to a non-reflecting position parallel to the substrate **800**. The reflectors **805***a–d* that are to remain in the non-reflecting position can be electrostatically clamped in the non-reflecting position by the clamping voltage and the selected reflector is not clamped in the non-reflecting position. Accordingly, the selected reflector is positioned in the reflecting position and the other reflectors are moved to the non-reflecting positions.

First and second flexible elements **850***a–b*, **850***a'–b'* are attached to the associated reflectors **805***a–d* and the substrate **800**. The first and second flexible elements **850***a–d*, **850***a'–d'* allow the associated reflectors **805***a–d* to move between the reflecting and non-reflecting positions in response to the movement of the mechanical actuator. Otherwise, the first and second flexible elements **850***a–d*, **850***a'–d'* can hold the associated reflectors **805***a–d* in the respective reflecting positions. For example, as shown in FIG. **8**, the first and second flexible elements **850***b–c*, **850***b'–c'* allow reflectors **805***b–d* to be shifted, substantially parallel to the substrate **800,** to the non-reflecting position by the mechanical actuator.

FIGS. **9**A–B are cross-sectional views illustrating exemplary operations of an embodiment of a 2×2 MEM OXC having a mechanical actuator **920** that moves substantially parallel to the substrate **800**. In the cross-sectional views of FIGS. **9**A–D, it will be understood that reflectors **905***a–b* can be occluded by reflectors **905***c–d*. According to FIG. **9**A, the mechanical actuator **920** is in the first mechanical actuator position and. the reflectors **905***a–d* are in the respective reflecting positions. The clamping voltage is applied to the reflectors **905***b–d* thereby coupling the reflectors **905***b–d* to the mechanical actuator **920**. The clamping voltage is not applied to the reflector **905***a*, thereby decoupling the reflector **905***a* from the mechanical actuator **920**. Alternatively, the mechanical actuator can include conductors that conduct the clamping voltage to areas of the mechanical actuator adjacent to the underlying respective reflectors. For example, the clamping voltage may be applied to the areas of the mechanical actuator while the reflectors **905***b–d* are grounded.

According to FIG. **9**B, the mechanical actuator **920** shifts from the first to the second mechanical actuator position in a direction **970** substantially parallel to the substrate **800**.

When the mechanical actuator **920** shifts from the first to the second mechanical actuator position, the coupled reflectors **905***b–d* are shifted to the respective non-reflecting positions.

FIG. **10** is a plan view of an embodiment of a reflector **1005** and attached first and second opposed flexible elements **1050, 1050'** on a substrate **800**. The first and second opposed flexible elements **1050, 1050** can allow the reflector **1005** to move in a direction **1070** substantially parallel to the substrate **800** between first and second mechanical actuator positions. The first and second opposed flexible elements **1050, 1050'** are attached to the substrate **800** by an anchor **1020**. The first and second opposed flexible elements **1050, 1050'** extend when the mechanical actuator moves the reflector **1005** from the first to the second reflector position.

FIG. **11** is a plan view of an embodiment of a reflector **1105** and first and second pairs of opposed flexible elements **1150, 1150'** and **1151, 1151'** on the substrate **800**. The first and second pairs of opposed flexible elements **1150, 1150'** and **1151, 1151'** allow the reflector **1105** to move in a direction **1170** substantially parallel to the substrate **800** between first and second mechanical actuator positions. The first and second pairs of opposed flexible elements **1150, 1150'** and **1151, 1151'** are attached to the substrate **800** by respective anchors **1120, 1120'**. When the mechanical actuator moves the reflector **1105** from the first to the second reflector position, the first and second pairs of opposed flexible elements **1150, 1150'** move to allow the reflector **1105** to move in the direction **1170**. In particular, the first pair of flexible opposed elements **1150, 1150'** extends in the direction **1170** and the second pair of flexible opposed elements **1151, 1151'** contracts in direction **1170**.

In the drawings and specification, there have been disclosed typical preferred embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention being set forth in the following claims.

What is claimed:

1. A microelectromechanical optical cross-connect switch that switches optical energy from an input of the microelectromechanical optical cross-connect switch to an output of the microelectromechanical optical cross-connect switch, the microelectromechanical optical cross-connect switch comprising:

a substrate

a plurality of reflectors, on the substrate, wherein the each of the plurality of reflectors is movable to at least one of a respective first reflector position along an optical beam path from an input of the microelectromechanical optical cross-connect switch to an output thereof and a respective second reflector position outside the optical beam path;

a mechanical actuator that is movable to at least one of a first mechanical actuator position and a second mechanical actuator position; and

a selector that selectively couples at least one of the plurality of reflectors to the mechanical actuator such that the at least one of the plurality of reflectors moves from the first reflector position to the second reflector position when the mechanical actuator moves from the first mechanical actuator position to the second mechanical actuator position.

2. A microelectromechanical optical cross-connect switch according to claim **1**, wherein the selector selectively decouples at least a second one of the plurality of reflectors from the mechanical actuator so that the at least second one of the plurality of reflectors remains in the first reflector position when the mechanical actuator moves from the first mechanical actuator position to the second mechanical actuator position.

3. A microelectromechanical optical cross-connect switch according to claim **1**, wherein the mechanical actuator moves from the first to the second mechanical actuator position in a direction of mechanical actuator movement that is substantially perpendicular to the substrate.

4. A microelectromechanical optical cross-connect switch according to claim **1**, wherein the first and second mechanical actuator positions define a plane that is substantially parallel to the substrate.

5. A microelectromechanical optical cross-connect switch according to claim **1** further comprising:

a plurality of flexible elements, on the substrate, a respective one of the plurality of flexible elements having a first portion attached to the substrate and a second portion, spaced-apart from the first portion, attached to a respective one of the plurality of reflectors, wherein the respective one of the plurality of flexible elements allows the attached respective one of the plurality of reflectors to move between the first and second reflector positions.

6. A microelectromechanical optical cross-connect switch according to claim **5**, wherein the respective one of the plurality of flexible elements includes a third portion spaced-apart from the first and second portions and attached to the substrate.

7. A microelectromechanical optical cross-connect switch according to claim **1** further comprising:

a first flexible element attached to a respective one of the plurality of reflectors and the substrate, wherein the respective one of the plurality of reflectors is coupled to the mechanical actuator and moves when the mechanical actuator moves from the first mechanical actuator, position to the second mechanical actuator position; and

a second flexible element attached to a respective second one of the plurality of reflectors and the substrate, wherein the respective second one of the plurality reflectors is decoupled from the, mechanical actuator and does not move when the mechanical actuator moves from the first mechanical actuator position to the second mechanical actuator position.

8. A microelectromechanical optical cross-connect switch according to claim **7**, wherein the first flexible element remains outside the optical beam path when the respective one of the plurality of reflectors is moved to the second reflector position.

9. A microelectromechanical optical cross-connect switch according to claim **7**, wherein the first flexible element remains substantially outside the optical beam path when the respective one of the plurality of reflectors is moved to the second reflector position.

10. A microelectromechanical optical cross-connect switch according to claim **7**, wherein the first flexible element includes a first portion attached to the substrate and a second portion, spaced-apart from the first portion, attached to the respective one of the plurality of reflectors, further comprising:

a third flexible element, on the substrate, spaced-apart from the first flexible element, the third flexible element having a first portion attached to the substrate and a second portion, spaced-apart from the first portion, attached to the respective one of the plurality of reflectors, wherein the third flexible element moves when the mechanical actuator moves from the first mechanical actuator position to the second mechanical actuator position.

11. A microelectromechanical optical cross-connect switch according to claim **10**, wherein the third flexible element is located substantially outside the optical beam path when the respective one of the plurality of reflectors is moved to the second reflector position.

12. A microelectromechanical optical cross-connect switch according to claim **7**, wherein at least one of the first and second flexible elements comprises a u-shaped zig-zag pattern.

13. A microelectromechanical optical cross-connect switch according to claim **7**, wherein at least one of the first and second flexible elements comprises a closed rectangular pattern.

14. A microelectromechanical optical cross-connect switch according to claim **7**, wherein at least one of the first and second flexible elements extends in a direction substantially perpendicular to the substrate when the mechanical actuator moves from the first to the second mechanical actuator position.

15. A microelectromechanical optical cross-connect switch according to claim **7**, wherein at least one of the first and second plurality of flexible elements extends in a direction substantially parallel to the substrate when the mechanical actuator moves from the first to the second mechanical actuator position.

16. A microelectromechanical optical cross-connect switch according to claim **1**, further comprising:

a plurality of trenches in the substrate adjacent the plurality of reflectors.

17. A microelectromechanical optical cross-connect switch according to claim **5**, further comprising:

a plurality of trenches in the substrate opposite the plurality of reflectors, wherein each of the plurality of flexible elements extends opposite the associated one of the plurality of trenches from the substrate to the associated one of plurality of reflectors.

18. A microelectromechanical optical cross-connect switch according to claim **1**, wherein the mechanical actuator comprises a conductive plate that is moved between the first and second mechanical actuator positions via at least one of an inductively driven servo and a stepper motor.

19. A microelectromechanical optical cross-connect switch according to claim **1**, wherein the selector comprises a plurality of conductors that conduct a voltage level to the selected ones of the plurality of reflectors to couple the selected ones of the plurality of reflectors to the mechanical actuator.

20. A microelectromechanical optical cross-connect switch that switches optical energy from an input of the microelectromechanical optical cross-connect switch to an output of the microelectromechanical optical cross-connect switch, the microelectromechanical optical cross-connect switch comprising:

a substrate;

a reflector, on the substrate, wherein the reflector is movable to at least one of a first reflector position along an optical beam path from an associated input of the microelectromechanical optical cross-connect switch to an associated output thereof and a second reflector position outside the optical beam path;

a mechanical actuator that is movable to at least one of a first mechanical actuator position and a second mechanical actuator position; and

a selector that selects a reflector to be coupled to the mechanical actuator, wherein a selected reflector is coupled to the mechanical actuator in the first mechanical actuator position so that the mechanical actuator moves the reflector from the first reflector position to the second position when the mechanical actuator moves from the first mechanical actuator position to the second mechanical actuator position.

21. A microelectromechanical optical cross-connect switch according to claim **20**, wherein the selector selects a reflector to be decoupled from the mechanical actuator and remain in the first reflector position when the mechanical actuator moves from the first mechanical actuator position to the second mechanical actuator position.

22. A microelectromechanical optical cross-connect switch according to claim **20**, wherein the mechanical actuator moves from the first to the second mechanical actuator position in a direction of mechanical actuator movement that is substantially perpendicular to the substrate.

23. A microelectromechanical optical cross-connect switch according to claim **20**, wherein the first and second mechanical actuator positions define a plane that is substantially parallel to the substrate.

24. A microelectromechanical optical cross-connect switch according to claim **20** further comprising:

a flexible element, on the substrate, the flexible element having a first portion attached to the substrate and a second portion, spaced-apart from the first portion, attached to the reflector, wherein the flexible element allows the reflector to move between the first and second reflector positions.

25. A microelectromechanical optical cross-connect switch according to claim **24**, wherein the flexible element includes a third portion spaced-apart from the first and second portions and attached to the substrate.

26. A microelectromechanical optical cross-connect switch according to claim **20** further comprising:

a second flexible element, on the substrate, the second flexible element having a respective first portion attached to the substrate and a respective second portion, spaced-apart from the first portion, attached to the reflector, wherein the second flexible element extends when the mechanical actuator moves from the first mechanical actuator position to the second mechanical actuator position.

27. A microelectromechanical optical cross-connect switch according to claim **26**, wherein the first and second flexible elements are located outside the optical beam path when the reflector is in the second reflector position.

28. A microelectromechanical optical cross-connect switch according to claim **26**, wherein at least one of the first and second flexible elements comprises a u-shaped zig-zag flexible element.

29. A microelectromechanical optical cross-connect switch according to claim **26**, wherein at least one of the first and second flexible elements comprises a closed rectangular shape.

30. A microelectromechanical optical cross-connect switch according to claim **26**, wherein at least one. of the first and second flexible elements extends in a direction substantially perpendicular to the substrate when the mechanical actuator moves from the first to the second mechanical actuator position.

31. A microelectromechanical optical cross-connect switch according to claim **26**, wherein at least one of the first and second flexible elements extends in a direction substantially parallel to the substrate when the mechanical actuator moves from the first to the second mechanical actuator position.

32. A microelectromechanical optical cross-connect switch according to claim **20**, further comprising:

a trench in the substrate adjacent the reflector, wherein a trench width and length are greater than a reflector width and length.

33. A microelectromechanical optical cross-connect switch according to claim **20**, wherein the mechanical actuator comprises a conductive plate that is moved between the first and second mechanical actuator positions via at least one of an inductively driven servo and a stepper motor least.

34. A microelectromechanical optical cross-connect switch that switches optical energy from an input of the microelectromechanical optical cross-connect switch to an output of the microelectromechanical optical cross-connect switch, the microelectromechanical optical cross-connect switch comprising:

a substrate;

a plurality of reflectors, on the substrate, wherein at least one of the plurality of reflectors is movable to at least one of a first reflector position along an optical beam path from an associated input of the microelectromechanical optical cross-connect switch to an associated output thereof and a second reflector position outside the optical beam path;

a mechanical actuator that moves selected ones of the plurality of reflectors from respective first reflector positions to respective second reflector positions; and

a selector that selects ones of the plurality of reflectors to remain in the second reflector position when the mechanical actuator moves from the second mechanical actuator position to the first mechanical actuator position.

35. A microelectromechanical optical cross-connect switch according to claim **34**, wherein the selector comprises a plurality of conductors electrically coupled to the plurality of reflectors, wherein the selected ones of the plurality of conductors conduct a clamping voltage level to the selected ones of the plurality of reflectors to maintain the selected ones of the plurality of reflectors in the respective second reflector positions when the mechanical actuator moves from the second mechanical actuator position to the first mechanical actuator position.

36. A microelectromechanical optical cross-connect switch that switches optical energy from an input of the microelectromechanical optical cross-connect switch to an output of the microelectromechanical optical cross-connect switch, the microelectromechanical optical cross-connect switch comprising:

a substrate;

a plurality of reflectors, on the substrate, wherein at least one of the plurality of reflectors is movable to at least one of a first reflector position along an optical beam path from an associated input of the microelectromechanical optical cross-connect switch to an associated output thereof and a second reflector position outside the optical beam path;

a mechanical actuator that moves selected ones of the plurality of reflectors from respective first reflector positions to respective second reflector positions; and

a selector that selects ones of the plurality of reflectors to be coupled to the mechanical actuator and at least one of the plurality of reflectors to be decoupled from the mechanical actuator, wherein the mechanical actuator is coupled to the selected ones of the plurality of reflectors in the first actuator position and wherein the mechanical actuator moves the selected ones of the plurality of reflectors from the respective first reflector positions to the respective second reflector positions when the mechanical actuator moves from the first mechanical actuator position to the second mechanical actuator position.

37. A microelectromechanical optical cross-connect switch according to claim **36**, wherein the selected at least one of the plurality of reflectors remains in the first reflector position when the mechanical actuator moves from the first mechanical actuator position to the second mechanical actuator position.

38. A microelectromechanical optical cross-connect switch according to claim **36**, wherein the first and second mechanical actuator positions define a plane that is substantially perpendicular to the substrate.

39. A microelectromechanical optical cross-connect switch according to claim **36**, wherein the first and second mechanical actuator positions define a plane that is substantially parallel to the substrate.

40. A microelectromechanical optical cross-connect switch according to claim **36** further comprising:

a plurality of flexible elements, on the substrate, each of the plurality of flexible elements having a first portion attached to the substrate and a second portion, spaced-apart from the first portion, attached to one of the plurality of reflectors, wherein each of the plurality of flexible elements allows the attached one of the plurality of reflectors to move between the first and second reflector positions.

41. A microelectromechanical optical cross-connect switch according to claim **40**, wherein each of the plurality of flexible elements includes a third portion spaced-apart from the first and second portions and attached to the substrate.

42. A microelectromechanical optical cross-connect switch according to claim **36** further comprising:

a plurality of flexible elements, on the substrate, each of the plurality of flexible elements having a first portion attached to the substrate and a second portion, spaced-apart from the first portion attached to one of the plurality of reflectors, wherein ones of the plurality of flexible elements attached to the selected ones of the plurality of reflectors move when the mechanical actuator moves from the first mechanical actuator position to the second mechanical actuator position and at least one of the plurality of flexible elements attached to the selected at least one of the plurality of reflectors holds the selected at least one of the plurality of reflectors in the first reflector position when the mechanical actuator moves from the first mechanical actuator position to the second mechanical actuator position.

43. A microelectromechanical optical cross-connect switch according to claim **42**, wherein the ones of the plurality of flexible elements attached to the at least one of the plurality of reflectors are located outside the optical beam path when the at least one of the plurality of reflectors is moved to the second reflector position.

44. A microelectromechanical optical cross-connect switch according to claim **42**, wherein the ones of the plurality of flexible elements attached to the at least one of the plurality of reflectors are located substantially outside the optical beam path when the at least one of the plurality of reflectors is moved to the second reflector position.

45. A microelectromechanical optical cross-connect switch according to claim **41** further comprising:

a plurality of second flexible elements, on the substrate, spaced-apart from the plurality of first flexible elements, each of the plurality of second flexible elements having a first portion attached to the substrate and a second portion, spaced-apart from the first portion, attached to one of the plurality of reflectors, wherein ones of the plurality of second flexible elements attached to the selected ones of the plurality of reflectors move when the mechanical actuator moves from the first mechanical actuator position to the second mechanical actuator position and at least one of the plurality of second flexible elements attached to the selected at least one of the plurality of reflectors holds the selected at least one of the plurality of reflectors in the first reflector position when the mechanical actuator moves from the first mechanical actuator position to the second mechanical actuator position.

46. A microelectromechanical optical cross-connect switch according to claim **45**, wherein the ones of the plurality of second flexible elements attached to the at least one of the plurality of reflectors are located substantially outside the optical beam path when the at least one of the plurality of reflectors is moved to the second reflector position.

47. A microelectromechanical optical cross-connect switch according to claim **41**, wherein at least one of the plurality of flexible elements comprises a u-shaped zig-zag flexible element.

48. A microelectromechanical optical cross-connect switch according to claim **41**, wherein at least one of the plurality of flexible elements comprises a w-shaped zig-zag flexible element.

49. A microelectromechanical optical cross-connect switch according to claim **41**, wherein at least one of the plurality of flexible elements extends in a direction substantially perpendicular to the substrate when the mechanical actuator moves from the first to the second mechanical actuator position.

50. A microelectromechanical optical cross-connect switch according to claim **41**, wherein at least one of the plurality of flexible elements extends in a direction substantially parallel to the substrate when the mechanical actuator moves from the first to the second mechanical actuator position.

51. A microelectromechanical optical cross-connect switch according to claim **36**, further comprising:

a plurality of trenches in the substrate opposite the plurality of reflectors.

52. A microelectromechanical optical cross-connect switch according to claim **40**, further comprising:

a plurality of trenches in the substrate opposite the plurality of reflectors, wherein each of the plurality of flexible elements extends opposite the associated one of the plurality of trenches from the substrate to the associated one of plurality of reflectors.

53. A microelectromechanical optical cross-connect switch according to claim **36**, wherein the mechanical actuator comprises a conductive plate that is moved between the first and second mechanical actuator positions via at least one of an inductively driven servo and a stepper motor least.

54. A microelectromechanical optical cross-connect switch according to claim **36**, wherein the selector comprises a conductor that conducts a plurality of voltage levels to the selected ones of the plurality of reflectors to couple the selected ones of the plurality of reflectors to the mechanical actuator.

55. A method for switching optical energy from an input of a microelectromechanical optical cross-connect switch to an output thereof, the method comprising the steps of:

coupling at least one of a plurality of reflectors at respective first reflector positions to a mechanical actuator along an optical beam path from an associated input of the microelectromechanical optical cross-connect switch to an associated output thereof;

moving the mechanical actuator from a first mechanical actuator position to a second mechanical actuator position to move the at least one of the plurality of reflectors to respective second reflector positions outside the optical beam path; and

decoupling at least one of the plurality of reflectors from the mechanical actuator in the first mechanical actuator position so that the at least one of the plurality of reflectors remains in the first reflector position along the optical beam path when the mechanical actuator moves from the first to the second mechanical actuator position.

56. A method according to claim **55**, wherein the step of moving comprises the step of moving the mechanical actuator along a path substantially parallel to a substrate of the microelectromechanical optical cross-connect switch.

57. A method according to claim **55**, wherein the step of moving comprises the step of moving the mechanical actuator along a path substantially perpendicular to a substrate of the microelectromechanical optical cross-connect switch.

58. A method for switching optical energy from an input of a microelectromechanical optical cross-connect switch to an output thereof, the method comprising the steps of:

coupling at least one of a plurality of reflectors at respective first reflector positions to a mechanical actuator along an optical beam path from an associated input of the microelectromechanical optical cross-connect switch to an associated output thereof;

moving the mechanical actuator from a first mechanical actuator position to a second mechanical actuator position to move the at least one of the plurality of reflectors to respective second reflector positions outside the optical beam path;

moving the mechanical actuator from the second to the first mechanical actuator position; and

decoupling the coupled ones of the plurality of reflectors from the mechanical actuator in the first mechanical actuator position.

59. A method for switching optical energy from an input of a microelectromechanical optical cross-connect switch to an output thereof, the method comprising the steps of:

coupling at least one of a plurality of reflectors at respective first reflector positions to a mechanical actuator along an optical beam path from an associated input of the microelectromechanical optical cross-connect switch to an associated output thereof,

moving the mechanical actuator from a first mechanical actuator position to a second mechanical actuator position to move the at least one of the plurality of reflectors to respective second reflector positions outside the optical beam path; and

decoupling the coupled ones of the plurality of reflectors from the mechanical actuator in the second mechanical actuator position.

60. A method for switching optical energy from an input of a microelectromechanical optical cross-connect switch to an output thereof, the method comprising the steps of:

coupling at least one of a plurality of reflectors at respective first reflector positions to a mechanical actuator along an optical beam path from an associated input of the microelectromechanical optical cross-connect switch to an associated output thereof, and

moving the mechanical actuator from a first mechanical actuator position to a second mechanical actuator position to move the at least one of the plurality of reflectors to respective second reflector positions outside the optical beam path, wherein the step of coupling comprises the step of applying a clamping voltage level to the ones of the plurality of reflectors to electrostatically couple the ones of the plurality of reflectors to the mechanical actuator.

61. A method for switching optical energy from an input of a microelectromechanical optical cross-connect switch to an output thereof, the method comprising the steps of:

coupling at least one of a plurality of reflectors at respective first reflector positions to a mechanical actuator along an optical beam path from an associated input of the microelectromechanical optical cross-connect switch to an associated output thereof; and

moving the mechanical actuator from a first mechanical actuator position to a second mechanical actuator position to move the at least one of the plurality of reflectors to respective second reflector positions outside the optical beam path, wherein the step of moving comprises the steps of moving the mechanical actuator from the first to the second mechanical actuator position to contact ones of the plurality of reflectors to move the contacted ones of the plurality of reflectors from the first reflector position substantially perpendicular to the optical beam path to the second reflector position substantially parallel to the optical beam path and clamping ones of the plurality of reflectors in the second reflector position.

62. A method according to claim **61**, further comprising the steps of:

moving the mechanical actuator from the second mechanical actuator position; and

allowing selected ones of the plurality of reflectors to move from the second to the first reflector position.

63. A method according to claim **55**, further comprising the step of:

transmitting optical energy from the input to the output along the optical beam path.

* * * * *